LUDLUM MODEL 14C-RK
RESPONSE KIT

April 2016

Serial Number 260716 and Succeeding

Serial Numbers

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PN: 48-2653

LUDLUM MEASUREMENTS, INC
501 OAK STREET, P.O. BOX 810
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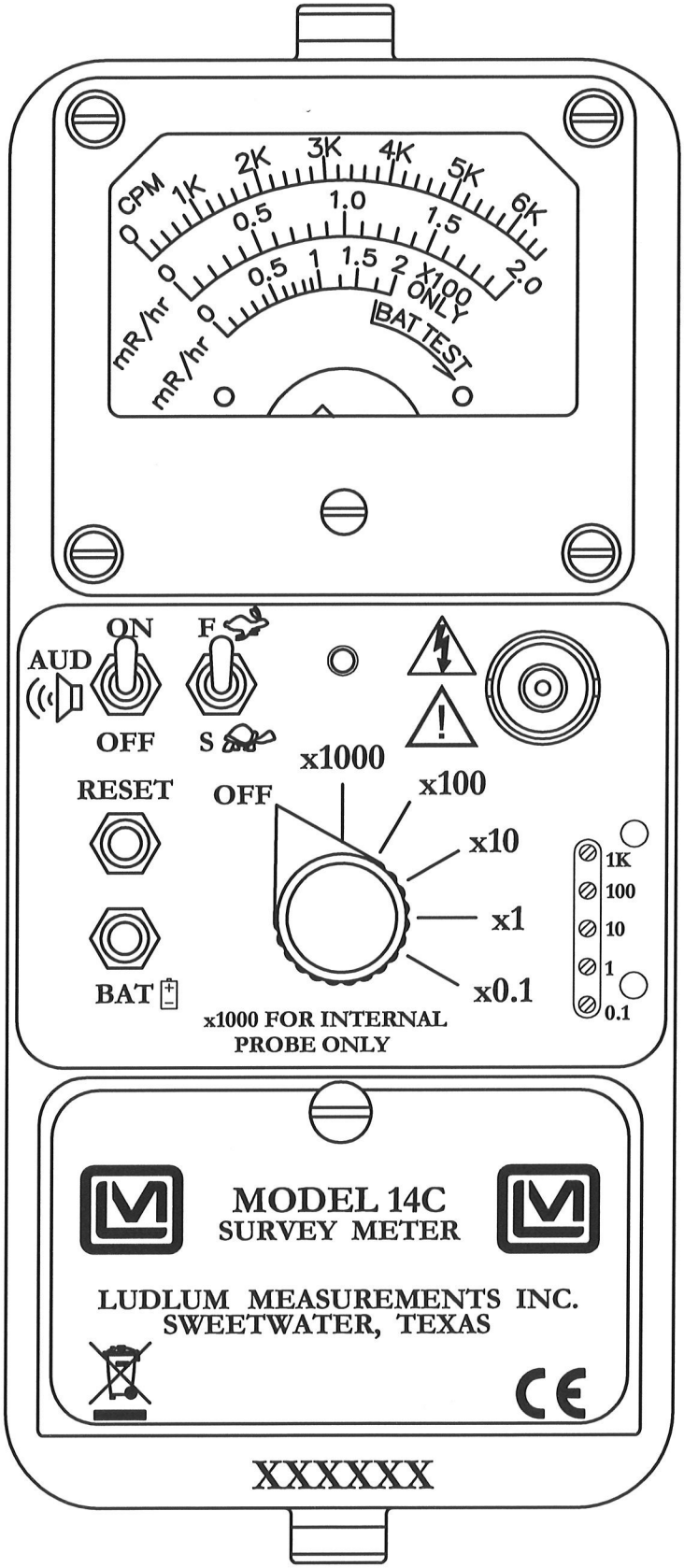
REV #	ALTERATIONS	DATE	BY
1	VALID	10/25/03	PW
2	REDESIGN	2/6/06	PW
3	UPDATED BATTERY LID	8/12/06	CMC



DWN	DATE	CHECKED	APPROVED
CMC	8/12/06		JOW 8-19-06

TITLE: MODEL 14C ASSY

LUDLUM MEASUREMENTS, INC.
501 OAK STREET
SWEETWATER, TEXAS 79556

SERIES 464

SHEET 180

Table of Contents

Introduction *1*

Instrument 1-1

External Detectors 1-1

Internal Detector 1-2

Getting Started *2*

Unpacking and Repacking 2-1

Battery Installation 2-1

Connecting a Detector to the Instrument 2-2

Battery Test 2-2

Instrument Test 2-2

Reading the Meter Face Dial 2-3

Operational Check 2-4

Survey Techniques 2-5

Specifications *3*

Instrument 3-1

Model 44-9 Detector 3-2

Model 44-2 Detector 3-3

Internal Detector 3-3

Description of Controls and Functions *4*

Safety Considerations *5*

Environmental Conditions for Normal Use 5-1

Cleaning Instructions and Precautions 5-1

Warning Markings and Symbols 5-2

Radiation Basics *6*

Radiation and Life 6-1

The Unstable Atom 6-2

Radioactive Decay 6-3

Ionizing Radiation 6-4

Measuring Ionizing Radiation 6-5

What are the Health Risks from Ionizing Radiation? 6-6

How Much Ionizing Radiation is Dangerous? 6-7
Background Radiation 6-10
Manmade Radiation 6-11
Protection from Radiation 6-11
Standards and Regulations 6-12
Who is in Charge? 6-12

Calibration and Maintenance *7*
Calibration 7-1
Establishing an Operating Point 7-1
Setting Overload 7-2
Range Calibration 7-3
Maintenance 7-3
Recalibration 7-3
Batteries 7-3
Detector Model 44-9 Tube Replacement Procedure 7-4

Troubleshooting *8*
Troubleshooting Electronics that utilize a
G-M or Scintillation type Detector 8-1
Troubleshooting G-M Detectors 8-3
Troubleshooting Scintillators 8-4

Technical Principle of Operation *9*

Recycling *10*

Parts List *11*
Model 14C Survey Meter 11-1
Main Board, Drawing 464 × 454 11-1
HV Power Supply Board, Drawing 464 × 302 11-3
Wiring Diagram, Drawing 464 × 175 11-4
Model 44-9 Alpha-Beta-Gamma Detector (Pancake) 11-5
Model 44-2 Gamma Scintillator 11-5

Drawings and Diagrams *12*

Section

1

Introduction

The Model 14C-RK is a first-responder kit designed for the rugged use of first-responders in the measuring of ionizing radiation. A rugged waterproof airtight carrying case with foam insert, check source with holder and detector cable are provided. Case weight is 3.08 kg (6.8 lb) empty, 5.9 kg (13 lb) with instruments.

Instrument

The Model 14C is a rugged splash-proof portable survey instrument that operates on two standard "D" cell alkaline batteries. The instrument features a regulated high-voltage power supply set at 900 volts and provides five linear ranges for measurement from 0 to 2000 mR/hr.

The unit body is made of rugged cast aluminum, including the meter housing. The can is made of 0.090" aluminum. Operating features of the instrument include a unimorph speaker mounted to the instrument can, an audio ON/OFF switch, fast/slow meter response switch, meter reset button, battery check button and 6-position switch for selecting scale multiples of ×0.1, ×1, ×10, ×100 and ×1000. Each range multiplier has its own calibration potentiometer. External detector operating voltage is set to 900 volts.

The unit is operated with two "D" cell alkaline batteries for operation from -20 to 50 °C (-4 to 122 °F) ; may be certified for operation from -40 to 65 °C (-40 to 150 °F). For operation in temperatures below 0 °C (32 °F), very fresh alkaline batteries or rechargeable NiCd batteries should be used. Battery drain is typically 5-7 mA in low radiation fields. Battery life is typically 2000 hours with alkaline batteries (battery condition can be checked on meter).

External Detectors

The response kit GM (Geiger-Mueller) "pancake" detector (Model 44-9) will detect alpha, beta, and gamma radiation. Its size and shape provide easy handling for surveying or personnel monitoring. The detector is energy dependant, over-responding by a factor of 6 (to gamma radiation) in the 60 keV-100 keV range when normalized to ^{137}Cs. The response of this detector is nominally linear (within 10%) from 1 mR/hr to 300 mR/hr.

This detector operates at 900 volts. The recommended instrument input sensitivity (set at calibration) is approximately 30 ±10 mV to prevent the detector from double pulsing.

The thin mica window in this detector is protected by a 79% open stainless steel screen. The GM tube can be easily removed for replacement if necessary. The GM tube face may rupture above 2438 m (8000 ft) altitude pressure. Consequently, tube failure is likely if transported above this altitude in an aircraft not pressurized.

The response kit sodium iodide (Nal) gamma scintillator (Model 44-2) is used for the detection of low-level gamma radiation, in the range of 60 keV to 1.25 MeV. The detector is energy dependant, over-responding by a factor of 10 or greater in the 100 keV range, and under-responding by a factor of 0.5 above 1 MeV when normalized to ^{137}Cs. The response of this detector is nominally linear (within 10%of true value), from 5 μR/hr to 50 mR/hr.

This detector consists of a 2.54 cm (1 in.) diameter by 2.54 cm (1 in.) thick, Nal crystal, coupled to a photomultiplier tube, and is housed in 0.157 cm (0.062 in.) thick aluminum housing. Recommended instrument sensitivity is approximately 10 mV or higher. Operating voltage varies from one detector to another.

Common applications for this detector include background radiation monitoring and low-level radiation detection.

Internal Detector

In addition to the two external detectors, an internal energy-compensated high-range detector is utilized. This internal detector may be used to measure high level gamma radiation fields using the ×1000 scale. In addition, the internal detector is active at all times, driving the meter full scale (to the right) when a high-radiation field is encountered.

Section

2

Getting Started

Unpacking and Repacking

Remove the calibration certificate and place it in a secure location. Remove the instrument and accessories (batteries, cable, etc.) and ensure that all of the items listed on the packing list are in the carton. Check individual item serial numbers and ensure calibration certificates match. The Model 14C serial number is located on the front panel below the battery compartment. Most Ludlum Measurements, Inc. detectors have a label on the base or body of the detector for model and serial number identification.

Important!

If multiple shipments are received, ensure that the detectors and instruments are not interchanged. Each instrument is calibrated to specific detectors, and therefore not interchangeable.

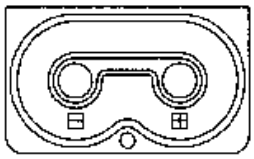
To return an instrument for repair or calibration, provide sufficient packing material to prevent damage during shipment. Also provide appropriate warning labels to ensure careful handling. Include detector(s) and related cable(s) for calibration

Every returned instrument must be accompanied by an Instrument Return Form, which can be downloaded from the Ludlum website at www.ludlums.com. Find the form by clicking the "Support" tab and selecting "Repair and Calibration" from the drop-down menu. Then choose the appropriate Repair and Calibration division where you will find a link to the form.

Battery Installation

Ensure the Model 14C range selector switch is in the OFF position. Open the battery lid by pushing down and turning the quarter-turn thumbscrew

counterclockwise a quarter of a turn. Install two ″D″ size batteries in the compartment.



Note the (+) and (-) marks inside the battery door. Match the battery polarity to these marks. Close the battery box lid, push down and turn the quarter-turn thumb screw clockwise a quarter of a turn.

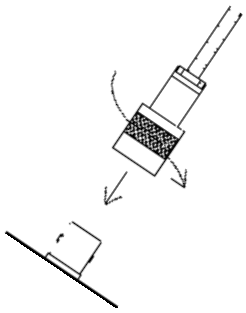
Note:

Center post of a flashlight battery is positive. The batteries are placed in the battery compartment in opposite directions.

Connecting a Detector to the Instrument

Caution!

The detector operating voltage (HV) is supplied to the detector via the detector input connector. A mild electric shock may occur if bodily contact is made with the center pin of the input connector. Switch the Model 14C range selector switch to the OFF position before connecting or disconnecting the cable or detector.



Connect one end of a detector cable to one of the detectors by firmly pushing the connectors together while twisting clockwise a quarter of a turn. Repeat the process in the same manner with the other end of the cable and the instrument.

Battery Test

The batteries should be checked each time the instrument is turned on. Move the range switch to the ×1000 position and press the BAT button. Ensure that the meter needle deflects to the BAT TEST portion on the meter scale. If the meter does not respond, check to see if the batteries have been correctly installed. Replace the batteries if necessary.

Instrument Test

After checking the batteries, turn the instrument range switch to the ×1000 position. Place the AUD ON-OFF switch in the ON position. Expose the internal detector to a check source. The instrument speaker should emit

″clicks″ relative to the rate of counts detected. The AUD ON/OFF switch will silence the audible clicks if in the OFF position. It is recommended that the AUD ON/OFF switch be kept in the OFF position when not needed in order to preserve battery life.

Utilizing one of the external detectors, rotate the range switch through the lower scales until a meter reading is indicated While observing the meter fluctuations, select between the fast and slow response time (″F/S″) positions to observe variations in the display. The ″S″ position should respond approximately five times slower than the ″F″ position.

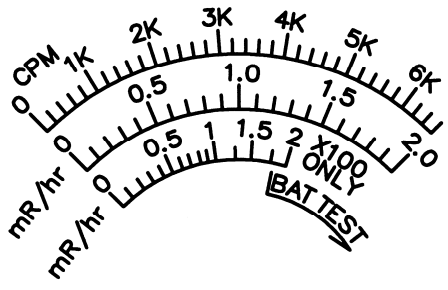
> **Note:**
>
> The slow response position is normally only used when the instrument is displaying low numbers, which require a more stable meter movement, or when making precise measurements. The fast response position is used at all other times.

Check the meter reset function by depressing the RES pushbutton switch and ensuring the meter needle drops to 0.

Once this procedure has been completed, the instrument is ready for use.

Reading the Meter Face Dial

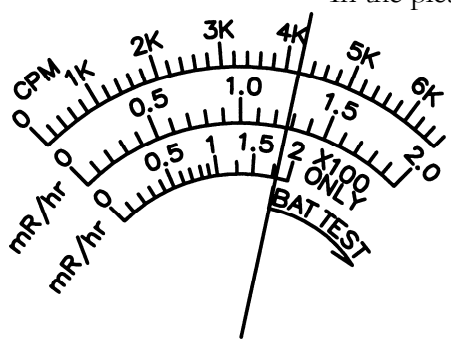
After checking the battery response, turn the instrument range selector switch to the highest range, and if no readings are seen on the meter, turn the selector switch down to the lower scales until a reading is seen. The ranges on the instrument selector switch are multipliers for the meter readings. The typical meter dial supplied with the response kit is displayed to the left.



This dial has three arcs: a count per minute scale (CPM), a linear mR/hr scale, and a non-linear mR/hr scale for the ×100 range ONLY.

The top CPM scale is valid for the ×0.1, ×1 and ×10 ranges. The linear (middle) mR/hr scale is valid for the ×0.1, ×1, ×10 and ×1000 ranges. The non-linear mR/hr scale is valid for the ×100 range ONLY. This meter face is commonly referred to as a "combo" meter face, since it has both count rate (CPM) and exposure rate (mR/hr) arcs. Simpler meter faces may only have a count rate or an exposure rate arc.

The "combo" meter face supplied in the response kit (unless otherwise specified) is specifically designed for use with the pancake (Model 44-9) detector. In the example above, the 1.0 mR/hr mark on the middle arc lines up with 3.3 kcpm on the upper arc. This meter face is designed to work with a detector that receives 3.3 kcpm per mR/hr (the Ludlum Model 44-9 pancake detector). When using the Ludlum Model 44-2 scintillator (included in the response kit), the CPM range is the only valid range. The mR/hr scale is not valid for any additional detector.



In the picture to the left, the needle is in the first tick mark past the 4 kcpm mark. So, if the instrument selector switch is on the ×0.1 range, the reading is 4.2 kcpm (multiplied by) ×0.1 = 420 cpm.

The same needle indication with different detectors would be:

Model 44-2:

×0.1 = 0.42 kcpm (or 420 cpm)
×1 = 4.2 kcpm (or 4200 cpm)
×10 = 42 kcpm (or 42,000 cpm)
×100 = 420 kcpm (or 420,000 cpm)
(*no m*R/*hr conversions*)

Model 44-9:

×0.1 = 0.13 mR/hr (or 420 cpm)
×1 = 1.3 mR/hr (or 4.2 kcpm)
×10 = 13 mR/hr (or 42 kcpm)
×100 = 180 mR/hr*

Internal Detector:

×1000 range only = 1.3 R/hr (*no cpm conversion*s)

Note:

*This reading is using the bottom (non-linear) scale.

Operational Check

To assure proper operation of the instrument between calibrations and periods of nonuse, an instrument operational check including battery test and instrument test (as described above) should be performed prior to use. A reference reading with a check source (included in the response kit)

should be obtained at the time of initial calibration or as soon as possible for use in confirming proper instrument operation. In each case, ensure a proper reading on each scale. If the instrument fails to read within 20% of a proper reading, it should be sent to a calibration facility for recalibration.

Survey Techniques

Note:

It is recommended that the instrument response (F/S) switch be placed in the F position during initial surveys.

Alpha: When using the Ludlum Model 14C Response Kit, the pancake detector (Model 44-9) must be used for detection of alpha.

Keep in mind that moisture or dirt may block alpha particles, making them impossible to be measured.

All shielding material must be removed from the suspected source.

When surveying for alpha, it is very important to get the window of the detector within 1.9 cm (0.75 in.) of the surface to be surveyed.

Move the detector over the area to be measured as slowly as possible (typically 2.5 to 5.1 cm {1 to 2 in.} per second) keeping in mind that the instrument response time is approximately four seconds when the F/S switch is in the F position.

Beta: To detect beta, the pancake detector (Model 44-9) must be used.

Move the detector over the area to be measured as slowly as possible (the instrument response time varies from 4 to 22 seconds).

Shielding may be utilized to determine the type of source (alpha or beta). Take a measurement with no shielding in place, then another with a piece of paper or other thin material placed over the suspected source.

Compare the first reading with the second to determine the amount of alpha and beta contribution. (This will be a very rough number.)

Gamma and X-ray: For gamma and high energy X-ray, the gamma scintillator (Model 44-2) must be used, reading the CPM scale only.

This detector is approximately 50 times more sensitive than the pancake (Model 44-9) detector. This detector is able to detect low level gamma and X-rays in the range of 60 keV to 1.25 MeV. This detector may be used for measurements up to 50 mR/hr.

The Model 44-2 is used by placing the detector in hand, and by slowly moving it from side to side over the area to be measured.

Be aware that the very end of the detector, opposite the connector, is the most sensitive. Point the detector towards the radiation being measured.

Section

3

Specifications

Instrument

Compatible Detectors: GM, Scintillation

Meter Dial: typically 0-2 mR/hr and CPM, BAT TEST (others available)

Ranges: 5 linear ranges from 0 to 2000 mR/hr; meter scale presentation of 0-2 mR/hr with multiples of ×0.1, ×1, ×10, ×100, and ×1000

Linearity: reading within 10% of true value with detector connected

Connector: series "C" (others available)

Energy Response: within 15% of true value between 60 keV and 3 MeV (internal detector only)

Input Sensitivity: -40 mV ±10 mV

Audio: built in unimorph speaker with ON/OFF switch (greater than 60 dB at 0.61 m {2 ft})

Calibration Controls: individual controls accessible from the front of the instrument (protective cover provided)

High Voltage: adjustable, nominally 700-1200 Vdc; set at 900 Vdc for internal detector operation.

Response: toggle switch for FAST (4 seconds) or SLOW (22 seconds) from 10% to 90% of final reading

Reset: pushbutton to "zero" the meter

Power: 2 each "D" cell batteries (housed in an externally accessible sealed compartment)

Battery Dependence: instrument calibration change of less than 3% within the meter face BAT TEST limits

Battery Life: typically greater than 2000 hours with alkaline batteries (battery condition may be checked on the meter face)

Meter: 6.5 cm (2.5 in.) arc, 1 mA analog type

Construction/Finish: cast and drawn aluminum with beige powder coat paint

Size Model 14C: 16.5 x 8.9 x 21.6 cm (6.5 x 3.5 x 8.5 in.) (H x W x D)

Weight Model 14C : 1.6 kg (3.5 lb) including batteries; 1.2 kg (2.6 lb) without batteries

Size Overall Kit: 43.2 x 29.7 x 15.7 cm (17 x 11.7 x 6.2 in.) (H x W x D)

Weight Case: 3.08 kg (6.8 lb) empty, 5.9 kg (13 lb) with instruments

Model 44-9 Detector

Indicated Use: alpha-beta-gamma survey and frisking

Detector: pancake-type halogen quenched Geiger-Muller (GM)

Window: 1.7 ± 0.3 mg/cm^2 mica

Window Area: active is 15 cm^2, open is 12 cm^2

Efficiency (4π geometry): typically 5% for ^{14}C, 22% for ^{90}Sr^{90}Y, 19% for ^{99}Tc, 32% for ^{32}P, and 15% for ^{239}Pu

Sensitivity: typically 3300 cpm per mR/hr (^{137}Cs gamma)

Energy Response: energy dependent

Dead Time: typically 80 microseconds

Operating Voltage: 900 Vdc

Construction: aluminum housing with beige powder-coat paint

Size: 4.6 x 6.9 x 27.2 cm (1.8 x 2.7 x 10.7 in.) (H x W x L)

Weight: 0.5 kg (1 lb)

Model 44-2 Detector

Indicated Use: low level gamma detection

Scintillator: 2.5 cm (1 in.) diameter x 2.5 cm (1 in.) thick; sodium iodide (NaI) T1 scintillator

Sensitivity: typically 175 cpm per uR/hr (^{137}Cs gamma)

Tube: 2.9 cm (1.1 in.) diameter; magnetically shielded photomultiplier

Operating Voltage: typically 500 to 1200 volts

Dynode String Resistance: 100 megohm

Construction: aluminum housing with beige powder-coat paint

Size: 5.1 x 18.5 cm (2 x 7.3 in.) (Dia x L)

Weight: 0.5 kg (1 lb)

Internal GM Detector

Type: energy compensated GM (used with the ×1000 scale only)

Sensitivity: approximately 200 cpm per mR/hr

Operating Voltage: operates at 900 Vdc

Size: 5.0 x 0.86 cm (1.96 x 0.34 in.) (L x Dia)

Section

4

Description of Controls and Functions

Range Multiplier Selector Switch: a six-position switch marked OFF, ×1000, ×100, ×10, ×1, ×0.1. Moving the range selector switch to one of the range multiplier positions (×1000, ×100, ×10, ×1, ×0.1) provides the operator with an overall range of 0-2000 mR/hr. Multiply the scale reading by the multiplier to determine the actual scale reading.

AUDIO ON/OFF Toggle Switch: In the ON position, the switch energizes the unimorph speaker, located on the left side of the instrument. The frequency of the clicks is relative to the rate of the incoming pulses. The higher the rate, the higher the audio frequency. The audio should be turned OFF when not required to reduce battery drain.

Fast Slow Toggle Switch: provides meter response. Selecting the fast, "F", position of the toggle switch provides 90% of final meter reading within 4 seconds. In the slow, "S", position, 90% of the final meter reading takes approximately 22 seconds. Set this switch to the "F" position for fast response and large meter deviation. The "S" position should be used for slow response and damped meter deviation.

RESET Button: When depressed, this button provides a rapid means to drive the meter to 0.

BAT Check Button: When depressed, this button provides a visual means of checking the battery charge status. The instrument must be turned ON to perform this check.

Range Calibration Adjustments: Recessed potentiometers are located under the calibration cover on the right side of the front panel for use in range calibration adjustments. These controls allow individual calibration for each range multiplier.

Section

5

Safety Considerations

Environmental Conditions for Normal Use

Indoor or Outdoor use

Maximum altitude of 2438 m (8000 ft) above sea level

Temperature range of -20 to 50 °C (-4 to 122 °F); may be certified for operation from -40 to 65 °C (-40 to 150 °F)

Maximum relative humidity of less than 95% (non-condensing)

Pollution Degree 2 (as defined by IEC 664) (Normally only nonconductive pollution occurs. Temporary conductivity caused by condensation is to be expected.)

Cleaning Instructions and Precautions

The Model 14C-RK instrument and detectors may be cleaned externally with a damp cloth, using only water as the wetting agent. Do not immerse the instrument or detectors in any liquid. Observe the following precautions when cleaning:

1. Turn the instrument OFF and remove the batteries.
2. Allow the instrument to sit for one minute before cleaning.

Caution!

Verify instrument voltage input rating before connecting to a power converter. If the wrong power converter is used, the instrument and/or power converter could be damaged.

Warning Markings and Symbols

Caution!

The operator or responsible body is cautioned that the protection provided by the equipment may be impaired if the equipment is used in a manner not specified by Ludlum Measurements, Inc.

The Model 14C is marked with the following symbols:

CAUTION (per ISO 3864, No. B.3.1) – designates hazardous live voltage and risk of electric shock. During normal use, internal components are hazardous live. This instrument must be isolated or disconnected from the hazardous live voltage before accessing the internal components. This symbol appears on the front panel. **Note the following precautions:**

Warning!

The operator is strongly cautioned to take the following precautions to avoid contact with internal hazardous live parts that are accessible using a tool:

1. Turn the instrument power OFF and remove the batteries.
2. Allow the instrument to sit for one minute before accessing internal components.

CAUTION, RISK OF ELECTRIC SHOCK (per ISO 3864, No. B.3.6) – designates a terminal (connector) that allows connection to a voltage exceeding 1 kV. Contact with the subject connector while the instrument is on or shortly after turning off may result in electric shock. This symbol appears on the front panel.

The "**crossed-out wheelie bin**" symbol notifies the consumer that the product is not to be mixed with unsorted municipal waste when discarding; each material must be separated. The symbol is placed on the battery lid. See section 10, "Recycling," for further information.

The "CE" mark is used to identify this instrument as being acceptable for use within the European Union.

Section

6

Radiation Basics

Radiation and Life

Adapted from Eric J. Hall's book, "Radiation and Life"

Radiation is energy traveling through space. Sunshine is one of the most familiar forms of radiation. It delivers light, heat, and suntans. We control its effect on us with sunglasses, shade, air conditioners, hats, clothes and sunscreen.

There would be no life on earth without lots of sunlight, but we have increasingly recognized that too much of it on our bodies is not a good thing. In fact, it may be dangerous, so we control our exposure to it.

Sunshine consists of radiation in a range of wavelengths from long-wave infrared to short-wavelength ultraviolet, which creates the hazard.

Beyond ultraviolet are higher energy kinds of radiation, which are used in medicine and which we all get in low doses from space, from the air, and from the earth. Collectively we can refer to these kinds of radiation as **ionizing radiation**. It can cause damage to matter, particularly living tissue. At high levels it is therefore dangerous, so it is necessary to control our exposure.

Background radiation is that which is naturally and inevitably present in our environment. Levels of this can vary greatly. People living in granite areas or on mineralized sands receive more terrestrial radiation than others, while people living or working at high altitudes receive more cosmic radiation. A lot of our natural exposure is due to radon, a gas which seeps from the earth's crust and is present in the air we breathe.

The Unstable Atom

Radiation comes from atoms, the basic building blocks of matter.

Most atoms are stable; a ^{12}C atom, for example, remains a ^{12}C atom forever, and an ^{16}O atom remains an ^{16}O atom forever, but certain atoms eventually disintegrate into a totally new atom. These atoms are said to be 'unstable' or 'radioactive'. An unstable atom has excess internal energy, with the result that the nucleus can undergo a spontaneous change towards a more stable form. This is called 'radioactive decay'.

When an atom of a radioisotope decays, it gives off some of its excess energy as radiation in the form of gamma rays or fast-moving sub-atomic particles. One can describe the emissions as gamma, beta, and alpha radiation.

Apart from the normal measures of mass and volume, the amount of radioactive material is given in **curie** (Ci), a measure which enables us to compare the typical radioactivity of some natural and other materials.

Radioactivity of some natural and other materials

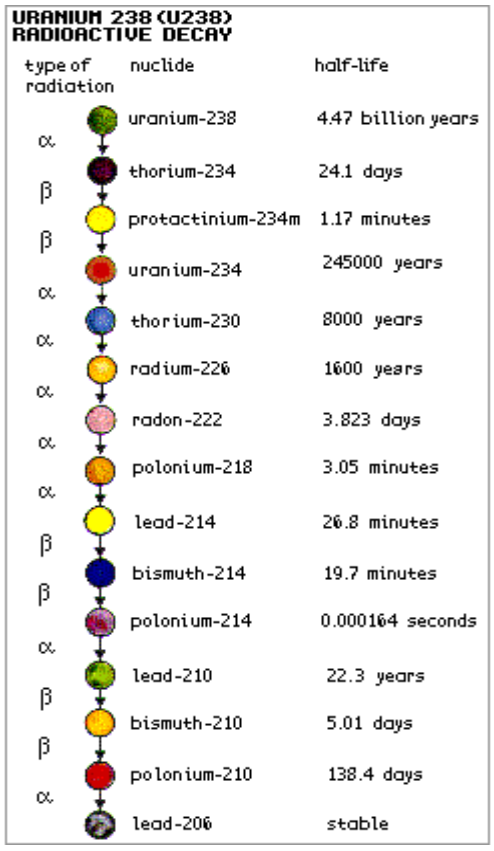
1 adult human (2.7×10^{-9} Ci/kg)	1.89×10^{-7} Ci
1 kg (2.2 lb) of coffee	2.70×10^{-8} Ci
1 kg (2.2 lb) of super phosphate fertilizer	1.35×10^{-7} Ci
The air in a 1076 sq. foot Australian home (radon)	8.12×10^{-8} Ci
The air in many 100 sq. m (1076 sq. ft) European homes (radon)	8.12×10^{-7} Ci
1 household smoke detector (with americium)	8.12×10^{-7} Ci
Radioisotope for medical diagnosis	1.89×10^{3} Ci
Radioisotope source for medical therapy	2702.7 Ci
1 kg (2.2 lb) of 50-year old vitrified high-level nuclear waste	270.27 Ci
1 luminous Exit sign (1970s)	27.027 Ci
1 kg (2.2 lb) of uranium	675.68×10^{6} Ci
1 kg (2.2 lb) of uranium ore (Canadian, 15%)	675.68×10^{6} Ci

1 kg (2.2 lb) of uranium ore (Australian, 0.3%)	13.51 X 10^{6} Ci
1 kg (2.2 lb) of low-level radioactive waste	27.03 X 10^{6} Ci
1 kg (2.2 lb) of coal ash	5.41 X 10^{-8} Ci
1 kg (2.2 lb) of granite	2.70 X 10^{-8} Ci

NB. Though the intrinsic radioactivity is the same, the radiation dose received by someone handling a kilogram of high grade uranium ore will be much greater than for the same exposure to a kilogram of separated uranium, since the ore contains a number of short-lived decay products (see section on Radioactive Decay).

Radioactive Decay

Atoms in a radioactive substance decay in a random fashion but at a characteristic rate. The length of time this takes, the number of steps required, and the kinds of radiation released at each step are well known.

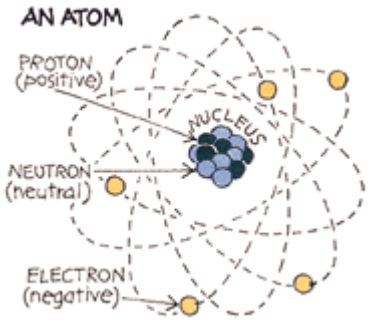


The half-life is the time taken for half of the atoms of a radioactive substance to decay. Half-lives can range from less than a millionth of a second to millions of years, depending upon the element concerned. After one half-life, the level of radioactivity of a substance is halved, after two half-lives it is reduced to one quarter, after three half-lives to one-eighth and so on.

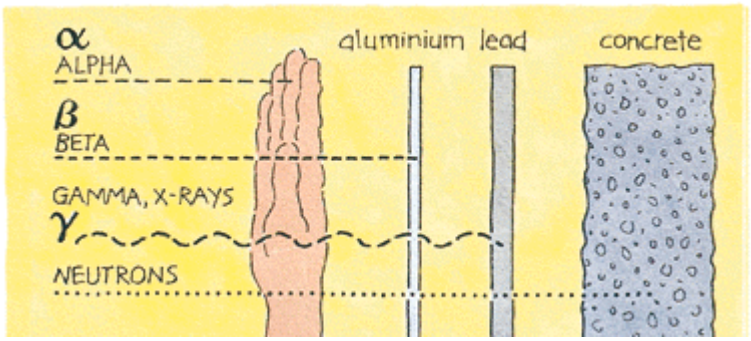
All uranium atoms are mildly radioactive. The following figure for ^{238}U (uranium-238) shows the series of different radioisotopes it becomes as it decays, the type of radiation given off at each step and the half-life of each step on the way to stable, non-radioactive ^{206}Pb (lead-206). The radioisotopes with the shortest half-lives emit more radiation per unit mass. Much of the natural radioactivity in rocks and soil comes from this decay chain.

Ionizing Radiation

Here we are concerned mainly with ionizing radiation from the atomic nucleus. It occurs in two forms – rays and particles – at the high frequency end of the energy spectrum.



There are several types of ionizing radiation:



X-rays and gamma rays, like light, represent energy transmitted in a wave without the movement of material, just as heat and light from a fire or the sun travel through space. X-rays and gamma rays are virtually identical, except that X-rays are generally produced artificially rather than coming from the atomic nucleus. Unlike light, X-rays and gamma rays have great penetrating power and can pass through the human body. Thick barriers of concrete, lead, or water are used as protection from them.

Alpha particles consist of two protons and two neutrons, in the form of atomic nuclei. They thus have a positive electrical charge and are emitted from naturally occurring heavy elements such as uranium and radium, as well as from some man-made elements. Because of their relatively large size, alpha particles collide readily with matter and lose their energy

quickly. They therefore have little penetrating power and can be stopped by the first layer of skin or a sheet of paper.

However, if alpha sources are taken into the body, for example by breathing or swallowing radioactive dust, alpha particles can affect the body's cells. Inside the body, because they give up their energy over a relatively short distance, alpha particles can inflict more severe biological damage than other radiations.

Beta particles are fast-moving electrons ejected from the nuclei of atoms. These particles are much smaller than alpha particles and can penetrate up to 0.20 cm (0.078 in. or 5/64 of an inch) of water or human flesh. Beta particles are emitted from many radioactive elements. They can be stopped by a sheet of aluminum a few millimeters thick.

Neutrons are particles which are also very penetrating. On Earth they mostly come from the splitting, or fissioning, of certain atoms inside a nuclear reactor. Water and concrete are the most commonly used shields against neutron radiation from the core of the nuclear reactor.

Note:

It is important to understand that alpha, beta, gamma and X-radiation do not cause the body, or any object around the source, to become radioactive. However, most materials in their natural state (including body tissue) contain measurable amounts of radioactivity.

Measuring Ionizing Radiation

RAD and REM

The human senses cannot detect radiation or discern whether a material is radioactive. However, a variety of instruments can detect and measure radiation reliably and accurately.

The amount of ionizing radiation, or dose, received by a person is measured in terms of the energy absorbed in the body tissue, and is expressed in **RAD**. One rad is 0.01 joules deposited per kilogram of mass.

Equal exposure to different types of radiation expressed as RAD do not, however, necessarily produce equal biological effects. One rad of alpha radiation, for example, will have a greater effect than one rad of beta radiation. When we talk about radiation effects, we therefore express the radiation as effective dose, in a unit called the **REM** (Roentgen Equivalent Man).

Regardless of the type of radiation, one rem of radiation produces the same biological effect. (100 rem = 1 Sv)

Smaller quantities are expressed in 'mrem' (one thousandth) or 'µrem' (one millionth of a rem). We will use the most common unit, rem, here.

What Are The Health Risks From Ionizing Radiation?

It has been known for many years that large doses of ionizing radiation, much larger than background levels, can cause a measurable increase in cancers and leukemias (cancer of the blood) after some years delay. It must also be assumed, because of experiments on plants and animals, that ionizing radiation can also cause genetic mutations that affect future generations, although there has been no evidence of radiation-induced mutation in humans. At very high levels, radiation can cause sickness and death within weeks of exposure. (See table on next page.)

But what are the chances of developing cancer from low doses of radiation? The prevailing assumption is that any dose of radiation, no matter how small, involves a possibility of risk to human health. However, there is no scientific evidence of risk at doses below approximatly 5 rem in a short period of time or about 10 rem over a period of one year.

Higher accumulated doses of radiation might produce a cancer, which would only be observed several (up to 20) years after the radiation exposure. This delay makes it impossible to say with any certainty which of many possible agents were the cause of a particular cancer. In western countries, about a quarter of people die from cancers, with smoking, dietary factors, genetic factors, and strong sunlight being among the main causes. Radiation is a weak carcinogen, but undue exposure could certainly increase health risks.

On the other hand, large doses of radiation directed specifically at a tumor are used in radiation therapy to kill cancerous cells, and thereby often save lives (usually in conjunction with chemotherapy or surgery). Much larger doses are used to kill harmful bacteria in food, and to sterilize bandages and other medical equipment. Radiation has become a valuable tool in our modern world.

How Much Ionizing Radiation is Dangerous?

Radiation levels and their effects

The following table gives an indication of the likely effects of a range of whole-body radiation doses and dose rates to individuals:

1000 rem as a short-term and whole-body dose would cause immediate illness, such as nausea and decreased white blood cell count, and subsequent death within a few weeks. Between 200 and 1000 rem in a short-term dose would cause severe radiation sickness with increasing likelihood that this would be fatal.
100 rem in a short term dose is about the threshold for causing immediate radiation sickness in a person of average physical attributes, but would be unlikely to cause death. Above 100 rem, severity of illness increases with dose. If doses greater than 100 rem occur over a long period they are less likely to have early health effects, but they create a definite risk that cancer will develop many years later.
Above about **10 rem**, the probability of cancer (rather than the severity of illness) increases with dose. The estimated risk of fatal cancer is 5 of every 100 persons exposed to a dose of 100 rem (ie. if the normal incidence of fatal cancer were 25%, this dose would increase it to 30%).
5 rem is, conservatively, the lowest dose at which there is any evidence of cancer being caused in adults. It is also the highest dose which is allowed by regulation in any one year of occupational exposure. Dose rates greater than 5 rem/yr arise from natural background levels in several parts of the world but do not cause any discernible harm to local populations.

2 rem/yr averaged over 5 years is the limit for radiological personnel such as employees in the nuclear industry, uranium, or mineral sands miners and hospital workers (who are all closely monitored).
1 rem/yr is the maximum actual dose rate received by any Australian uranium miner.
300-500 mrem/yr is the typical dose rate (above background) received by uranium miners in Australia and Canada.
300 mrem/yr (approx) is the typical background radiation from natural sources in North America, including an average of almost 200 mrem/yr from radon in air.
200 mrem/yr (approx) is the typical background radiation from natural sources, including an average of 70mrem/yr from radon in air. This is close to the minimum dose received by all humans anywhere on Earth.
30-60 mrem/yr is a typical range of dose rates from artificial sources of radiation, mostly medical.
5 mrem/yr, a very small fraction of natural background radiation, is the design target for maximum radiation at the perimeter fence of a nuclear electricity generating station. In practice, the actual dose is less.

What is the risk estimate?

According to the Biological Effects of Ionizing Radiation committee V (BEIR V), the risk of cancer death is 0.08% per rem for doses received rapidly (acute) and might be 2-4 times (0.04% per rem) less than that for doses received over a long period of time (chronic). These risk estimates are an average for all ages, males and females, and all forms of cancer. There is a great deal of uncertainty associated with the estimate.

Risk from radiation exposure has been estimated by other scientific groups. The other estimates are not the exact same as the BEIR V estimates, due to differing methods of risk and assumptions used in the calculations, but all are close.

Risk comparison

The real question is, "How much will radiation exposure increase my chances of cancer death over my lifetime?".

To answer this, we need to make a few general statements of understanding. One is that in the US the current death rate from cancer is approximately 20%, so out of any group of 10,000 United States citizens, about 2000 of them will die of cancer. Second, that contracting cancer is a random process,

where given a set population, we can estimate that about 20 percent will die from cancer, but we cannot say *which* individuals will die. Finally, that a conservative estimate of risk from low doses of radiation is thought to be one in which the risk is linear with dose. That is, that the risk increases with a subsequent increase in dose. Most scientists believe that this is a conservative model of the risk.

Risk estimates: If you were to take a large population, such as 10,000 people and expose them to one rem (to their whole body), you would expect approximately eight additional deaths (0.08% X 10,000 X 1 rem). So, instead of the 2000 people expected to die from cancer naturally, you would now have 2008. This small increase in the expected number of deaths would not be seen in this group, due to natural fluctuations in the rate of cancer.

What needs to be remembered is that it is not known that 8 people will die, but that there is a risk of eight additional deaths in a group of 10,000 people if they would all receive 1 rem instantaneously.

If they would receive the 1 rem over a long period of time, such as a year, the risk would be less than half this (<4 expected fatal cancers).

Risks can be looked at in many ways. Here are a few ways to help visualize risk:

One way often used is to look at the number of "days lost" out of a population due to early death from separate causes, then dividing those days lost between the population to get an "Average Life expectancy lost" due to those causes. The following is a table of life expectancy lost for several causes:

Health Risk	**Est. life expectancy lost**
Smoking 20 cigarettes a day	6 years
Overweight (15%)	2 years
Alcohol (US Avg.)	1 year
All Accidents	207 days
All Natural Hazards	7 days
Occupational dose (300 mrem/yr)	15 days
Occupational dose (1 rem/yr)	51 days

You can also use the same approach to looking at risks on the job:

Industry Type	Est. life expectancy lost
All Industries	60 days
Agriculture	320 days
Construction	227 days
Mining and quarrying	167 days
Manufacturing	40 days
Occupational dose (300 mrem/yr)	15 days
Occupational dose (1 rem/yr)	51 days

These are estimates taken from the NRC Draft guide DG-8012 and were adapted from B.L Cohen and I.S. Lee, "Catalogue of Risks Extended and Updates", *Health Physics*, Vol. 61, September 1991.

Another way of looking at risk, is to look at the relative risk of one in a million chances of dying of activities common to our society:

Smoking 1.4 cigarettes (lung cancer)
Eating 40 tablespoons of peanut butter
Spending 2 days in New York City (air pollution)
Driving 64.3 km (40 mi) in a car (accident)
Flying 4023 km (2500 mi) in a jet (accident)
Canoeing for 6 minutes
Receiving 10 mrem of radiation (cancer)

Adapted from DOE Radiation Worker Training, based on work by B.L Cohen, Sc.D.

Background Radiation

Naturally occurring background radiation is the main source of exposure for most people. Levels typically range from about 150-350 mrem per year but can be more than 5rem/yr. The highest known level of background radiation affecting a substantial population is in Kerala and Madras States in India where some 140,000 people receive doses, which average over 1.5 rem/year from gamma radiation, in addition to a similar dose from radon. Comparable levels occur in Brazil and Sudan, with average exposures up to about 4 rem/yr to many people.

Several places are known in Iran, India and Europe where natural background radiation gives an annual dose of more than 5 rem and up to 26 rem (at Ramsar in Iran). Lifetime doses from natural radiation range

up to a couple thousand rem. However, there is no evidence of increased cancers or other health problems arising from these high natural levels.

Manmade Radiation

Ionizing radiation is also generated in a range of medical, commercial, and industrial activities. The most familiar and, in national terms, the largest of these sources of exposure is medical X-rays.

Natural radiation contributes about 88% of the annual dose to the population, and medical procedures most of the remaining 12%. Natural and artificial radiations are not different in kind or effect.

Protection from Radiation

Radiation is very easily detected. There is a range of simple, sensitive instruments capable of detecting minute amounts of radiation from natural and man-made sources. There are three ways in which people are protected from identified radiation sources:

Limiting time: For people who are exposed to radiation in addition to natural background radiation through their work, the dose is reduced and the risk of illness essentially eliminated by limiting exposure time. Proper job planning is essential in achieving lowest exposure time. Always plan for the unexpected to eliminate delays in the exposure area.

Distance: In the same way that heat from a fire is less the further away you are, so the intensity of radiation decreases with distance from its source. Distance is the easiest, fastest and most practical way to limit exposure.

Shielding: Barriers of lead, concrete, or water give good protection from penetrating radiation such as gamma rays. Highly radioactive materials are therefore often stored or handled under water, or by remote control in rooms constructed of thick concrete or lined with lead.

Standards and Regulations

Much of the evidence which has led to today's standards derives from the atomic bomb survivors in 1945, which were exposed to high doses incurred in a very short time. In setting occupational risk estimates, some allowance has been made for the body's ability to repair damage from small exposures, but for low-level radiation exposure, the degree of protection may be unduly conservative.

Most countries have their own systems of radiological protection, which are often based on the recommendations of the International Commission on Radiological Protection (ICRP). The authority of the ICRP comes from the scientific standing of its members and the merit of its recommendations.

Who is in charge?

Ultimately, you are. All of the sources of radiation, other than natural, are regulated by laws passed by Congress. Like any other law, you have your right to voice your views and opinions about it. The regulations that control the use of radioactivity in our country are based upon recommendations of science organizations like the International Commission on Radiological Protection (ICRP), the National Council on Radiation Protection (NCRP), the International Atomic Energy Agency (IAEA), the United Nations (UN), and the Health Physics Society (HPS). Governing bodies like the Environmental Protection Agency (EPA), the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), and the Food and Drug Administration (FDA) review these recommendations and propose the regulations that industry and government must follow. These are then passed by Congress, if found to be acceptable, and published in the Code of Federal Regulations (CFRs).

Note:

The CFR limits the general public to radiation exposure of 100 mrem/year, with no more than 2 mrem of exposure in any one hour (ref. 10 CFR 20.1301).

Section

7

Calibration and Maintenance

Calibration

Note:

Measure high voltage with a Ludlum Model 500 Pulser or a high-impedance voltmeter with a high-meg probe. If one of these instruments is unavailable, use a voltmeter with a minimum input resistance of 1000 megohm.

ESTABLISHING AN OPERATING POINT

Efficiency, background sensitivity, and noise are fixed by the physical makeup of the given detector and rarely vary from unit to unit. However, the selection of the operating point makes a significant difference in the contribution of these three sources of count.

The purpose of setting the operating point is to establish the system gain so that the desirable signal pulses (including background) are above the discrimination level, and the unwanted pulses from noise are below the discrimination level. The pulses above the discrimination level are counted by the instrument, while those below are not.

The total system gain is controlled by adjusting the instrument high voltage. Voltage affects the output of the detector. In special cases of GM detectors, a minimum voltage must be applied to establish the Geiger-Mueller characteristic.

The operating point for each detector is set at a compromise point between sensitivity, stability, and background contribution. These operating points are best for general monitoring. In application, these arbitrarily selected points may not be a better operating point.

The following guidelines are presented:

GM Detectors: The output pulse height of the GM detector is not proportional to the energy of the detected radiation. For most GM detectors set the HV to the GM tube recommended high voltage. Most GM detectors operate at 900 volts; however, some miniature detectors operate at 400-600 volts. If a recommended setting is unavailable, run a plateau of HV setting vs. count rate. Then set the high voltage on the low side of the plateau "center."

Scintillators: Carefully increase HV until the instrument plateaus on the background count. This provides the most stable operating point for the detector.

Note:

Access to the HV adjustment potentiometer is achieved by removal of the instrument housing. Potentiometer R8 on the HV power supply board is the control for this adjustment.

Warning!

Open instrument has shock potential! Do not allow any conductive material to come in contact with internal parts while making the following adjustments.

SETTING OVERLOAD

Set the instrument range selector multiplier switch to ×100.

On the HV power supply board, adjust R3 until the unit indicates over-range at 10 R/hr, and no over-range at 4 R/hr.

Note:

Over-range is indicated by full-scale meter reading on the ×100 scale.

RANGE CALIBRATION

Turn the instrument range multiplier selector switch to the appropriate range. Expose the detector to a calibrated gamma field, and adjust the respective range calibration potentiometer for proper reading.

Repeat the above procedure for the remaining ranges.

Maintenance

Instrument maintenance consists of keeping the instrument clean and periodically checking the batteries and calibration.

An instrument operational check should be performed prior to each use by exposing the detector to a known source and confirming the proper reading on each scale.

RECALIBRATION

Recalibration should be accomplished after any maintenance or adjustment has been performed on the instrument. Recalibration is not normally required after instrument cleaning or battery replacement. Ludlum Measurements recommends recalibration at intervals no greater than one year. Local regulations may have precedence over this recommendation.

BATTERIES

The batteries should be removed and the battery contacts cleaned of any corrosion at least every three months. If the instrument has been exposed to a very damp or corrosive atmosphere, more frequent battery servicing should be performed.

Use a spanner wrench to unscrew the battery contact insulators exposing the internal contacts and battery springs. Removal of the instrument handle will facilitate access to these contacts.

Note:

Never store this instrument longer than 30 days without removing the batteries. Although this instrument will operate at very high ambient temperatures, battery seal failure may occur at temperatures as low as 37.7 °C (100 °F).

DETECTOR MODEL 44-9 TUBE REPLACEMENT PROCEDURE

Consult the Model 44-9 Alpha-Beta-Gamma Detector drawing in Section 11 of this manual to perform the following:

Caution!

The mica window of this tube is *extremely thin* and can easily break. There is also a thin layer of material to prevent UV interference. This material may come off if touched, causing the detector to malfunction. DO NOT TOUCH.

1. Remove the back plate by removing the three screws.
2. Loosen the three set screws on the side of the tube housing.
3. Remove the old tube from the detector housing.
4. Remove the anode clip from the old tube.
5. Push the clip onto the anode housing.

Note:

Do not over-flex the wire when installing the clip!

6. Carefully install the tube with the window face down in the housing. Tighten the set screws evenly. The tube should be flush against the screen.
7. Replace the back plate and the retaining screws.
8. The detector is now ready for use.

Note:

The instrument and detector will need to be recalibrated once the above procedure is complete.

Section

8

Troubleshooting

Occasionally, you may encounter problems with your LMI instrument or detector that may be repaired or resolved in the field, saving turnaround time and expense in returning the instrument to us for repair. Toward that end, LMI electronics technicians offer the following tips for troubleshooting the most common problems. Where several steps are given, perform them in order until the problem is corrected. Keep in mind that with this instrument, the most common problems encountered are: (1) detector cables, (2) sticky meters, (3) battery contacts.

Note that the first troubleshooting tip is for determining whether the problem is with the electronics or with the detector. A Ludlum Model 500 Pulser is invaluable at this point, because of its ability to simultaneously check high voltage, input sensitivity or threshold, and the electronics for proper counting.

We hope these tips will prove to be helpful. As always, please call if you encounter difficulty in resolving a problem or if you have any questions.

Troubleshooting Electronics that utilize a GM or Scintillation type Detector

SYMPTOM	**POSSIBLE SOLUTION**
No power (or meter does not reach BAT TEST or BAT OK mark)	1. Check batteries and replace if weak. 2. Check polarity (see marks inside batter lid). Are the batteries installed backwards?

SYMPTOM	POSSIBLE SOLUTION
No power (or meter does not reach BAT TEST or BAT OK mark) (continued)	3. Check battery contacts. Clean them with rough sandpaper or use an engraver to clean the tips. 4. Remove the instrument can and check for loose or broken wires.
Nonlinear Readings	1. Check the high voltage (HV) using a Ludlum Model 500 Pulser. If a multimeter is used to check the HV, ensure that one with high impedance is used, as a standard multimeter could be damaged in this process. 2. Check for noise in the detector cable by disconnecting the detector, placing the instrument on the lowest range setting, and wiggling the cable while observing the meter face for significant changes in readings. 3. Check for "sticky" meter movement. Does the reading change when you tap the meter? Does the meter needle "stick" at any spot? 4. Check the "meter zero." Turn the power OFF or press RESET. The meter should come to rest on 0.
Meter goes full-scale or "Pegs Out"	1. Replace the detector cable to determine whether or not the cable has failed, causing excessive noise. 2. Check the HV, and if possible, the input threshold for proper setting.

SYMPTOM	POSSIBLE SOLUTION
Meter goes full-scale or "Pegs Out" (continued)	3. Ensure that the instrument's ″can″ is properly attached. When attached properly, the speaker will be located on the left side of the instrument. If the can is on backwards, interference between the speaker and the input preamplifier may cause noise.
No Response to Radiation	1. Substitute a "known well" detector and/or cable. 2. Has the correct operating voltage been set? Refer to the calibration certificate or detector instruction manual for correct operating voltage. If the instrument uses multiple detectors, confirm that the high voltage is matched to the current detector being used.
No Audio	1. Ensure that the AUD ON-OFF switch is in the ON position. 2. Remove the instrument housing and check the connection between the circuit board and the speaker. Plug in the 2-pin connector if found disconnected.

Troubleshooting GM Detectors

1. If the tube has a thin mica window, check for window breakage. If damage is evident, the tube must be replaced. See page 7-4 for Model 44-9 tube replacement instructions.

2. Check the HV. For most GM tubes, the voltage is normally 900 Vdc, or 460-550 Vdc for "peanut" tubes (Ludlum Model 133 series).

3. If the input sensitivity is too low, the user could see some double-pulsing.

4. Wires to the tube may be broken or the crimped connector could have a loose wire.

Troubleshooting Scintillators

1. Alpha or alpha/beta scintillators are prone to light leaks. They can be tested for this problem in a dark room or with a bright light. If a light leak is determined, changing the Mylar window assembly will usually fix the problem.

Note:

When replacing the window, make sure to use a window made with the same thickness Mylar and the same number of layers as the original window.

2. Verify that the HV and input sensitivity are correct. Alpha and gamma scintillators typically operate from 10-35 mV. High voltage varies with the photomultiplier tubes (PMT), from as low as 600 Vdc, to as high as 1400 Vdc.

3. On a gamma scintillator, visually inspect the crystal for breakage or humidity leakage. Water inside the crystal will turn it yellow and gradually degrade performance.

4. Check the PMT to see if the photocathode still exists. If the end of the PMT is clear (not brownish), this indicates a loss of vacuum, which will render the PMT useless.

Section 9

Technical Principle of Operation

Input

The external detector pulses are coupled from the detector through C4 to amplifier U9/U15/Q2. CR1 protects the amplifier from input shorts. R40 couples the detector to the high-voltage supply.

The internal detector (V1) is located on the HV power supply circuit board. V1 pulses are coupled through C6 to comparator U13 on the main circuit board. R46 and R47 set the comparator level to approximately 0.5 volts. R9 on the HV power supply circuit board limits the detector current. With the range selector switch on ×1K, U5B is closed, coupling high-range pulses to the counting circuitry.

The internal detector is used only when the range switch is in the ×1K position. In the ×0.1, ×1, ×10, and ×100 ranges, the external detector is used. When the range selector switch is on the 1K position, Q4 is saturated, blocking external detector pulses.

Amplifier

A self-biased amplifier provides gain in proportion to R43/C11, divided by R41 for the external detector. Transistor (pin 3 of U9) provides amplification. Pin 2 and 5 of U15 are coupled as a current mirror to provide a load for pin 3 of U9. The output self-biases to 2 Vbe (approximately 1.4 volts) at emitter of Q2. This provides just enough bias current through pin 2 of U9 to conduct all of the current from the current mirror.

Positive pulses from emitter of Q2 are coupled to the comparator U12.

Discriminator

Comparator U12 provides discrimination. The discriminator is set by the voltage divider, R9 and R25, coupled to pin 3 of U12. The comparator trip point is approximately 0.16 volts. U12 pulses are coupled to pin 5 of U7A for meter drive and pin 12 of U7B for audio.

Audio

Discriminator pulses are coupled to univibrator pin 12 of U7B. Front-panel audio ON/OFF selector controls the reset at pin 13 of U7B. When ON, pulses from pin 10 of U7B turn oscillator U17 on. Pin 5 of U17 drives the can-mounted unimorph. Speaker tone is set by R49, C20 duration by R48, C16.

Digital Analog Converter

Pins 2, 3, and 5 of U8 are coupled as a current mirror. For each pulse of current through R36, an equal current is delivered to C8. This charge is drained off by R38. The voltage across C8 is proportional to the incoming count rate.

Scale Ranging

Detector pulses from the discriminator are coupled to univibrator, pin 5 of U7A. For each scale, the pulse width of pin 6 of U7A is increased by a factor of 10 with the actual pulse width being controlled by the front-panel calibration controls and their related capacitors. This arrangement allows the same current to be delivered to C8 by one-tenth of a count on the ×0.1 range and 10 counts on the ×100 range.

Meter Drive

The meter is driven by the collector of Q1, coupled as a constant current source in conjunction with pin 1 of U10.

For battery test, U18A opens and U18B closes, and the meter movement is directly coupled to the battery through R31.

Fast/Slow Time Constant

For slow time constant, C7 is switched from the output of the meter drive to parallel C8.

Low Voltage Supply

Battery voltage is coupled to U16 and associated components (a switching regulator) to provide 5 volts at pin 8 to power all circuits.

High Voltage Supply

On the HV power supply circuit board, high voltage is developed by C1-T1 and rectified by voltage multiplier CR1–CR6. Output voltage increases as R8 is decreased.

High voltage is coupled back through R6 to pin 8 of U1. R7/R8 completes the high-voltage circuit to ground. High-voltage output is set by R8. During stable operation, the voltage at pin 8 of U1 will stabilize at approximately 1.2 volts.

Overload

The cathode of V1 is connected through R3 to ground. With R3 on the main board fully clockwise and the instrument in a 2 R/hr radiation field, voltage at the cathode ranges from 0.2 to 0.4 volts, depending on exact high-voltage setting and the internal tube.

The cathode voltage is conducted from the HV power supply board through P1 to pin 4, U11 on the main circuit board. Comparator U11 is biased at 0.22 volts. When pin 4, U11 exceeds 0.22 volts, U3B switch is closed, grounding R39, causing high current flow through R38 and causing the meter circuit to drive full-scale.

Low Battery Alarm

When the battery voltage drops to 2.2 volts, Pin 2 of U16 causes U5A switch to open, allowing Pin 3 of U17 to go high. The audio will make a continuous noise.

Switching

All switching, except FAST/SLOW and audio ON/OFF, is accomplished with analog switches. Switch schematics are shown enabled, although typically only one switch is enabled at any given time.

Section

10

Recycling

Ludlum Measurements, Inc. supports the recycling of the electronic products it produces for the purpose of protecting the environment and to comply with all regional, national, and international agencies that promote economically and environmentally sustainable recycling systems. To this end, Ludlum Measurements, Inc. strives to supply the consumer of its goods with information regarding reuse and recycling of the many different types of materials used in its products. With many different agencies – public and private – involved in this pursuit, it becomes evident that a myriad of methods can be used in the process of recycling. Therefore, Ludlum Measurements, Inc. does not suggest one particular method over another, but simply desires to inform its consumers of the range of recyclable materials present in its products, so that the user will have flexibility in following all local and federal laws.

The following types of recyclable materials are present in Ludlum Measurements, Inc. electronics products, and should be recycled separately. The list is not all-inclusive, nor does it suggest that all materials are present in each piece of equipment:

Batteries	Glass	Aluminum and Stainless Steel
Circuit Boards	Plastics	Liquid Crystal Display (LCD)

Ludlum Measurements, Inc. products, which have been placed on the market after August 13, 2005, have been labeled with a symbol recognized internationally as the "crossed-out wheelie bin." This notifies the consumer that the product is not to be mixed with unsorted municipal waste when discarding; each material must be separated. The symbol will be placed near the AC receptacle, except for portable equipment where it will be placed on the battery lid.

The symbol appears as such:

Section

11

Parts List

	Reference	Description	Part Number
Model 14C Survey Meter	UNIT	Completely Assembled Model 14C Survey Meter	48-1611
Main Board, Drawing 464 × 454	BOARD	Completely Assembled Main Circuit Board	5464-454
CAPACITORS	C1	47pF, 50V	04-5740
	C2	100pF, 100V	04-5661
	C3	100pF, 100V	04-5661
	C4	100pF, 3KV	04-5735
	C5	0.1µF, 35V	04-5755
	C6	0.0047µF, 100V	04-5669
	C7	47µF, 10V	04-5666
	C8	10µF, 25V	04-5655
	C9	1µF, 16V	04-5701
	C10	470pF, 100V	04-5668
	C11	10pF, 100V	04-5673
	C12	0.01µF, 50V	04-5664
	C13-C14	0.001µF, 100V	04-5659
	C15	100pF, 100V	04-5661
	C16	0.022µF, 50V	04-5667
	C17	68µF, 10V	04-5654
	C18	68µF, 10V	04-5654
	C19	1µF, 16V	04-5701
	C20	470pF, 100V	04-5668
	C21	0.001µF, 2KV	04-5703
	C22	1µf, 16V	04-5701
TRANSISTORS	Q1	MMBT4403LT1	05-5842
	Q2	MMBT3904LT1	05-5841
	Q3	2N7002L	05-5840
	Q4	MMBT3904LT1	05-5841

	Reference	Description	Part Number
INTEGRATED CIRCUITS	U1-U3	MAX4542ESA	06-6453
	U5	MAX4543ESA	06-6596
	U7	CD74HC4538M	06-6297
	U8-U9	CMXT3904	05-5888
	U10	LMC7111BIM5X	06-6410
	U11	MAX985EUK-T	06-6459
	U12-U13	MAX986EUK-T	06-6601
	U15	CMXT3906	05-5890
	U16	LT1304CS8-5	06-6434
	U17	MIC1557BM5	06-6457
	U18	MAX4543ESA	06-6596
DIODES	CR1	CMPD2004S	07-6402
	CR2	CMSH1-40M	07-6411
SWITCHES	S1	CENTRAL-2P6P, (RANGE)	08-6761
	S2	7101SDCQE, F/S	08-6781
	S3	TP11LTCQE, RESET	08-6770
	S4	TP11LTCQE, BAT TEST	08-6770
	S5	7101SDCQE, AUDIO	08-6781
POTENTIOMETERS	R14	250K, 64W254, ×1K	09-6819
	R27	250K, 64W254, ×10	09-6819
	R28	500K, 64W504, ×1	09-6850
	R29	250K, 64W254, ×0.1	09-6819
	R30	250K, 64W254, ×100	09-6819
RESISTORS	R1-R6	200K, 1/8W, 1%	12-7992
	R7-R8	100K, 1/8W, 1%	12-7834
	R9	68.1K, 1/8W, 1%	12-7881
	R10-R13	100K, 1/8W, 1%	12-7834
	R15-R19	10K, 1/8W, 1%	12-7839
	R20	100K, 1/8W, 1%	12-7834
	R21	4.75K, 1/8W, 1%	12-7858
	R22-R24	10K, 1/8W, 1%	12-7839
	R25	2.21K, 7/8W, 1%	12-7835
	R26	8.25K, 1/8W, 1%	12-7838
	R31	2.37K, 1/8W, 1%	12-7861
	R32	2K, 1/8W, 1%	12-7926
	R33	200 Ohm, 1/8W, 1%	12-7846
	R34	100K, 1/8W, 1%	12-7834
	R35	1K, 1/4W, 1%	12-7832

	Reference	Description	Part Number
	R36	14.7K, 1/8W, 1%	12-7068
	R37	68.1K, 1/8W, 1%	12-7881
	R38-R39	200K, 1/8W, 1%	12-7992
	R40	100K, 1/8W, 1%	12-7834
	R41-R42	4.75K, 1/8W, 1%	12-7858
	R43	165K, 1/8W, 1%	12-7877
	R44-R45	1K, 1/8W, 1%	12-7832
	R46	137K, 1/8W, 1%	12-7061
	R47	14.7K, 1/8W, 1%	12-7068
	R48	1M, 1/8W, 1%	12-7844
	R49	475K, 1/8W, 1%	12-7859
CONNECTORS	P1	640456-5, MTA100×5, CHASSIS CONNECTOR	13-8057
	P2	640456-4, MTA100×4, HV/×1K DET CONNECTOR	13-8088
	P3	640456-6, MTA100×6, ACCESSORY	13-8095
	P4	640456-2, MTA100×2, SPEAKER	13-8073
INDUCTOR	L1	22uH	21-9808
MISCELLANEOUS	W1	HV WIRE	**
	W1	EXT. DET. WIRE	**
HV Power Supply Board, Drawing 464 ×302	BOARD	Completely Assembled HV Power Supply Board	5464-302
CAPACITORS	C1	10uF, 25V	04-5655
	C2-C5	0.001uF, 2KV	04-5703
	C6	100PF, 3KV	04-5735
	C7-C12	0.01uF, 500V	04-5696
	C13	68uF, 10V	04-5654
	C14	0.1uF, 50V	04-5663
INTEGRATED CIRCUIT	U1	LT1304CS8	06-6394
DIODES	CR1-CR6	CMSD2004S	07-6417
	CR7	CMSH1-40M	07-6411

	Reference	Description	Part Number
POTENTIOMETERS	R3	25K, 8026EKX-253, OL ADJ.	09-6832
	R8	1M, 3266W1-105, HV ADJ	09-6778
RESISTORS	R1	1.5M, 1/4W, 1%	12-7987
	R2	100K, 1/4W, 1%	12-7834
	R4	1M, 1/4W, 1%	12-7844
	R5	4.75K, 1/4W, 1%	12-7858
	R6	500M, 3KV, 2%	12-7031
	R7	475K, 1/4W, 1%	12-7859
	R9	1M, 1/4W, 1%	12-7844
CONNECTORS	P5	640456-2, MTA100×2, ×1K TEST	13-8073
	P6	640456-4, MTA100×4 HV/1K DET	13-8088
TRANSFORMER	T1	31032R	21-9925
DETECTOR	V1	LND72611	4331-020
MISCELLANEOUS	W1	TEFLON WHITE EE22, HV	21-9759
	W2	#22 BLACK UL1430, NOT USED	21-9413

Wiring Diagram, Drawing 464 × 175

AUDIO	DS1	UNIMORPH 60690	21-9251
CONNECTORS	J1	640442-5 MTA100	13-8140
	J2	640442-4 MTA100	13-8170
	J3	640442-6 MTA100	13-8171
	J4-J5	640442-2 MTA100	13-8178
	J6	640442-4 MTA100	13-8170
BATTERY	B1-B2	"D" DURACELL BATTERY	21-9313
MISCELLANEOUS	FL2-FL4	WIRE	**
	W1	RECPT-UG706/U "C" LMI	4478-011
	M1	METER MOVEMENT	15-8030
	*	CABLE-C (STD 39-inch)	40-1004
	*	BATTERY LID W/STAINLESS CONTACT	2009-036
	*	PORTABLE BATTERY NEGATIVE CONTACT ASSEMBLY	2001-065
	*	PORTABLE BATTERY POSITIVE CONTACT ASSEMBLY	2001-066

	Reference	Description	Part Number
	*	CALIBRATION COVER WITH SCREWS	9363-200
	*	BEZEL W/MOVEMENT ASSY.	4363-572
	*	PORTABLE BEZEL GLASS W/O SCREWS	4363-352
	*	PORTABLE KNOB	08-6613
	*	CAN ASSEMBLY O-RING	16-8261
	*	LATCH KIT W/O PORTABLE BATTERY LID	7363-190
	*	PORTABLE HANDLE FOR CLIP WITH SCREWS	7363-203
	*	PROBE CLIP	7010-008-01
	*	CHECK SOURCE ^{137}Cs 37 kBq 1uCi	01-5196
	*	CHECK SOURCE HOLDER	4062-166
	*	CARRYING CASE	2313065
Model 44-9 Alpha-Beta-Gamma Detector (PANCAKE)	UNIT	Completely Assembled Model 44-9 Alpha-Beta-Gamma Detector	47-1539
	*	DETECTOR BODY	2002-109
	*	HANDLE GRIP	7002-426
	*	G-M TUBE (LND 7311) TGM N1002	01-5008
	*	SOCKET SET SCREWS (10-34 X 1/4), 3 EACH	17-8560
	*	PENCIL CLIP	01-5237
	*	RESISTOR, 3.3 MEGOHMS	10-7044
	*	CONNECTOR, UG 706/U	13-7751
	*	HV WIRE	21-9312
	*	PROTECTIVE SCREEN	21-9586
	*	RED PROTECTIVE CAP	03-5476
Model 44-2 Gamma Scintillator	UNIT	Completely Assembled Model 44-2 Gamma Scintillator	47-1532
	*	DETECTOR BODY	2002-084-01
	*	END CAP	7002-029-02
	*	1× 1 inch Nal CRYSTAL	40-5154
	*	1.5 inch TUBE/SOCKET ASSY.	4002-510
	*	TUBE SHIELD	40-4006

Reference	Description	Part Number
*	PM TUBE	01-5742
*	CONNECTOR UG 706/U	13-7751
*	TEFLON WIRE 4 ea.	21-9362
*	#26 BLACK WIRE 4 ea.	21-9558
*	LUG	18-8766
*	SCREWS 4 ea.	17-8811
*	SPONGE 6 ea.	7002-029-05
*	XTAL SIDE SPONGE 2 ea.	7002-276
BOARD	Completely Assembled Tube Socket Circuit Board Included in PM TUBE 01-5742	5002-502

Section

12

Drawings

Main Board, Drawing 464 × 454 (4 sheets)

Main Board Component Layout, Drawing 464 × 455A (2 sheets)

HV Power Supply Board, Drawing 464 × 302

HV Power Supply Board Component Layout, Drawing 464 × 303

Wiring Diagram, Drawing 464 × 175

Model 44-9 Alpha, Beta, Gamma Detector, Drawing 2 x 206

Energy Response for Ludlum Model 44-9

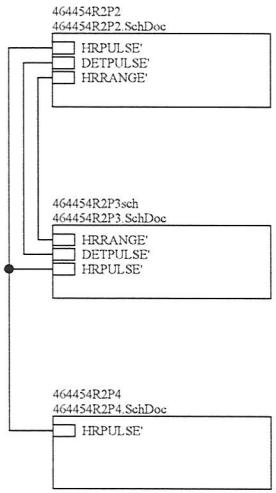
"New" Beta Source Efficiencies for Model 44-9

Model 44-2 Gamma Scintillator, Assembly View, Drawing 2 x 205A

1.5 inch Tube Socket Board Component Layout, Drawing 2 x 318

1.5 inch Tube Socket Board Schematic, Drawing 2 x 317

Energy Response Curve Model 44-2



LUDLUM MEASUREMENTS, INC.
PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828

Drawn: MC	02/24/2009	Title: MAIN BOARD		
Design: DL	02/24/2009	Model: 14C		
		Board#: 5464-454		
Approved:		Sheet: 1 of 4	Series	Sheet
Print Date: 3/4/2016 1:51:12 PM		Rev: 2	464	454

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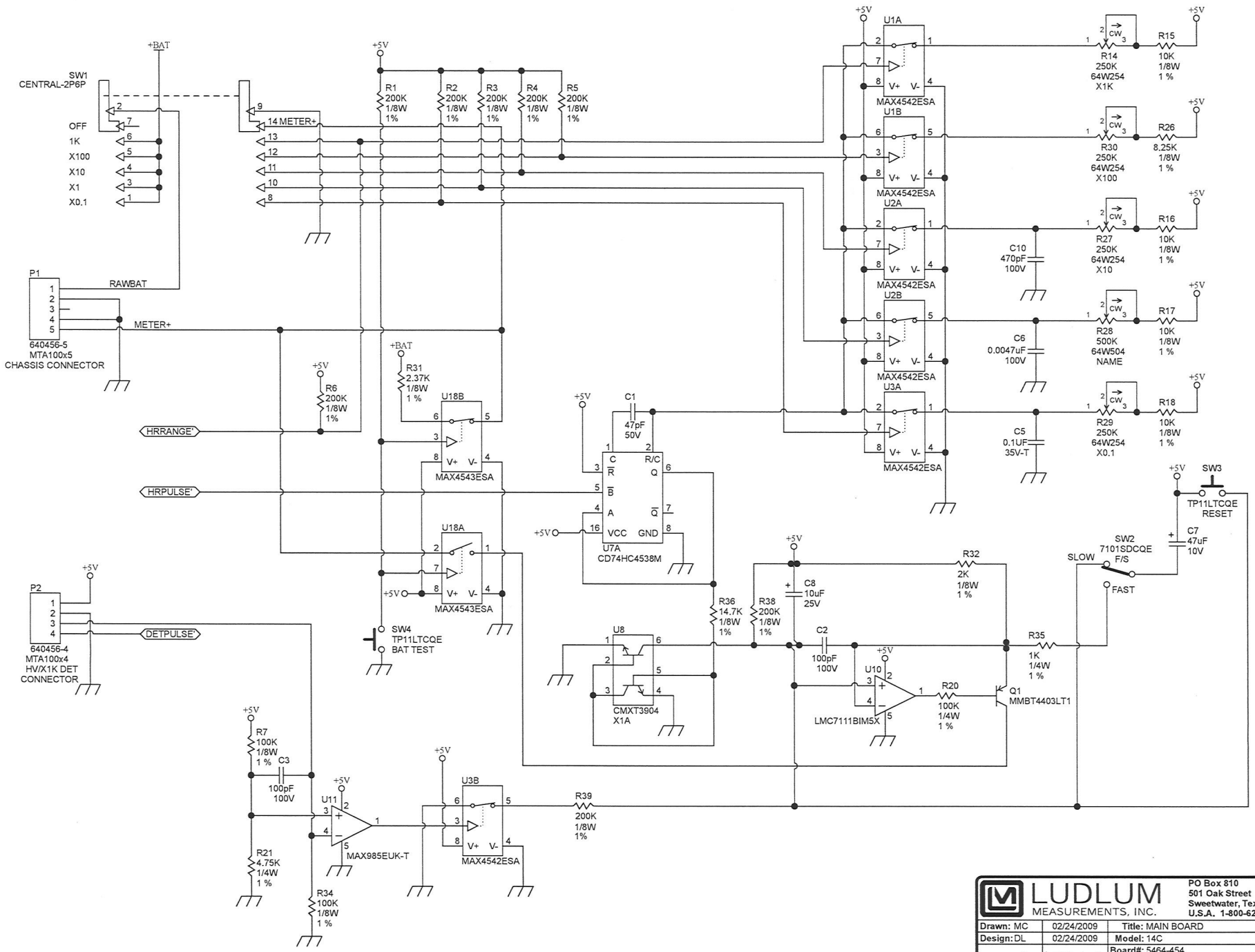

LUDLUM MEASUREMENTS, INC.		PO Box 810 501 Oak Street Sweetwater, Texas 79556 U.S.A. 1-800-622-0828	
Drawn: MC	02/24/2009	Title: MAIN BOARD	
Design: DL	02/24/2009	Model: 14C	
		Board#: 5464-454	
Approve:		Sheet: 2 of 4	Series 464 / Sheet 454
Print Date: 3/4/2016 1:51:12 PM		Rev: 2	
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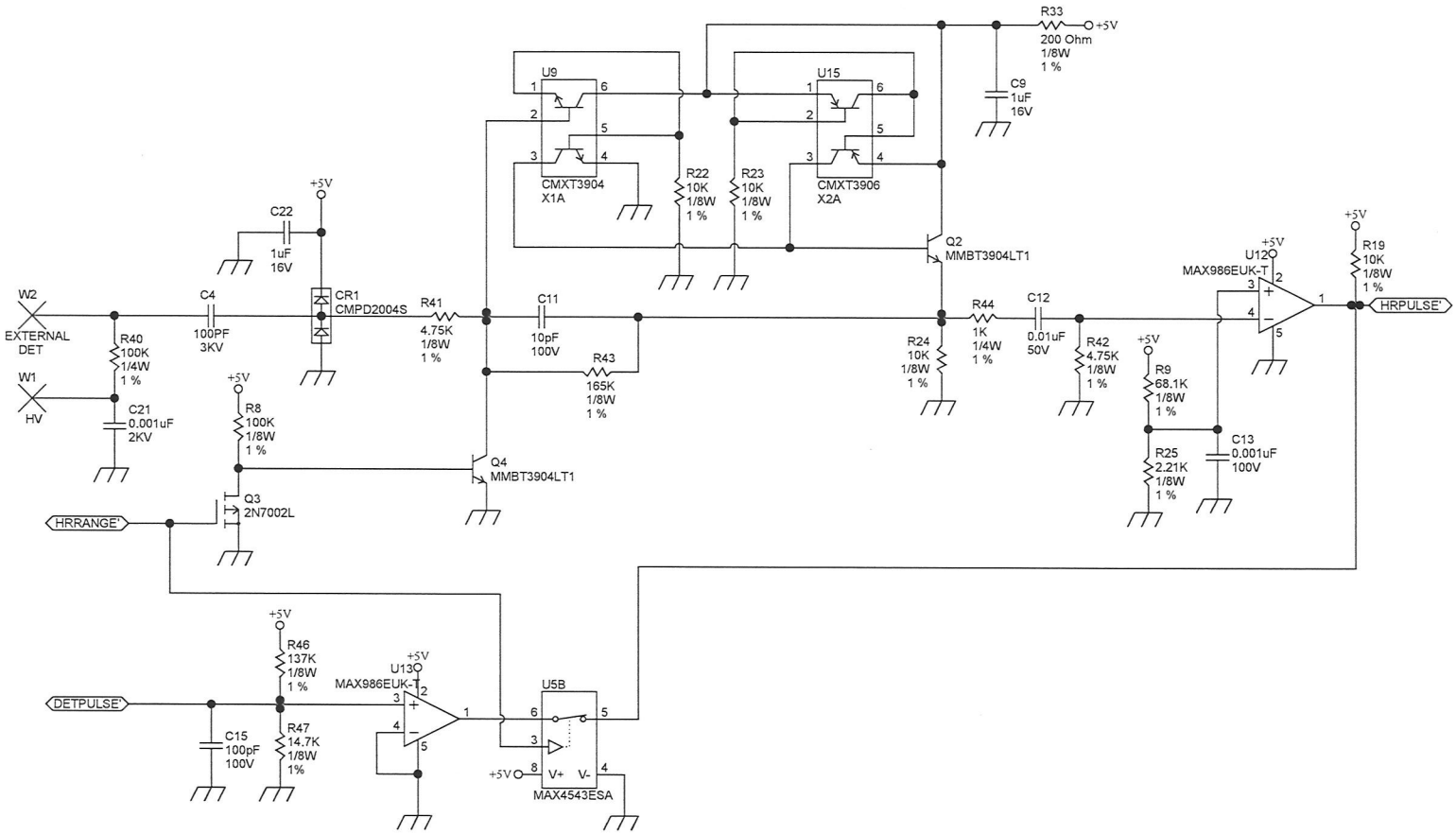

LUDLUM MEASUREMENTS, INC.		PO Box 810 501 Oak Street Sweetwater, Texas 79556 U.S.A. 1-800-622-0828	
Drawn: MC	02/24/2009	Title: MAIN BOARD	
Design: DL	02/24/2009	Model: 14C	
		Board#: 5464-454	
Approve: RH 4/17/2012		Sheet: 3 of 4	Series 464 / Sheet 454
Print Date: 3/4/2016 1:51:12 PM		Rev: 2	
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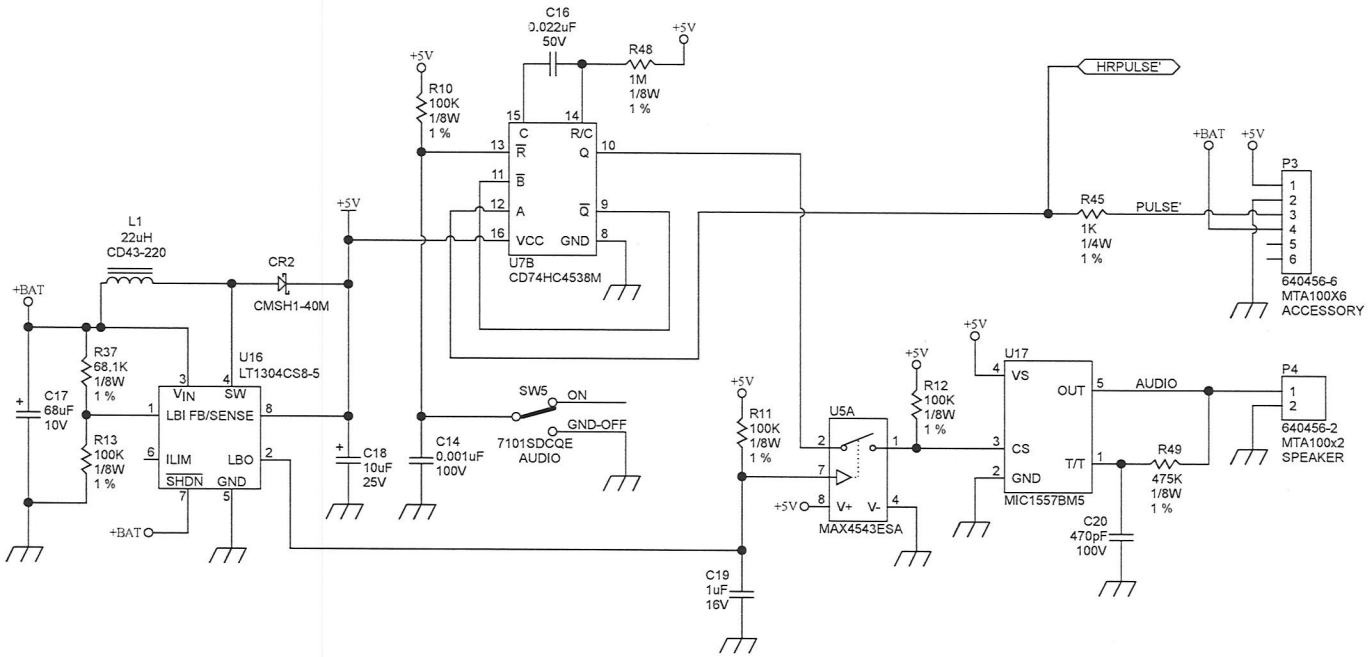

LUDLUM MEASUREMENTS, INC.		PO Box 810 501 Oak Street Sweetwater, Texas 79556 U.S.A. 1-800-622-0828	
Drawn: MC	02/24/2009	Title: MAIN BOARD	
Design: DL	02/24/2009	Model: 14C	
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Approve:		Sheet: 4 of 4	Series 464 / Sheet 454
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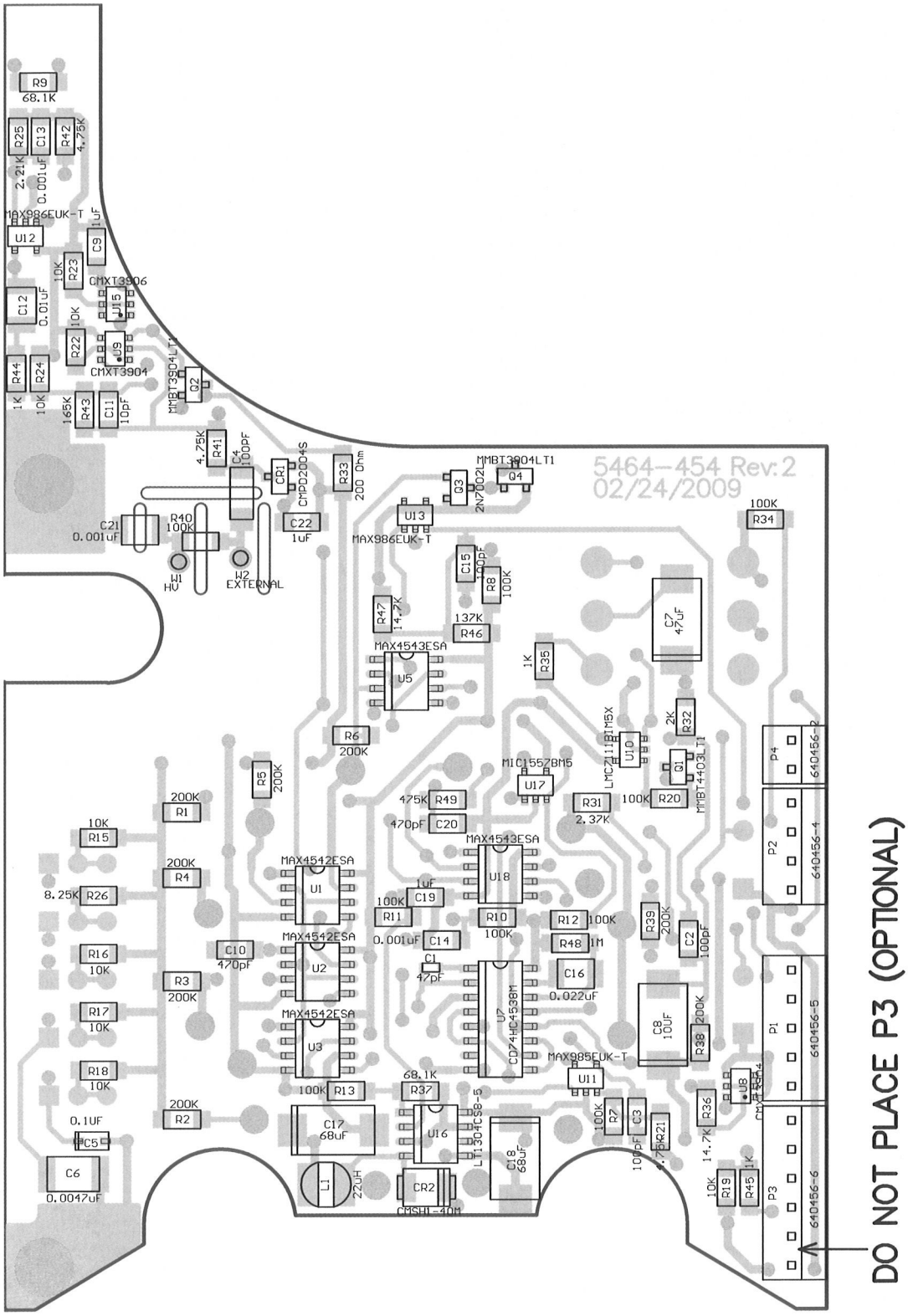

LUDLUM MEASUREMENTS, INC.		PO Box 810 501 Oak Street Sweetwater, TX 79556 U.S.A. 1-800-622-0828	
Title: MAIN BOARD			
Drawn: MC	02/24/2009	**Model:** 14C	
Design: DL	02/24/2009	**Board#:** 5464-454	
Approve: RDS	26 Jun 14	**Rev:** 2	
Print Date: 5/7/2014 2:31:55 PM		**SCALE: 1.00** Top Overlay	**Series** 464 / **Sheet** 455 A
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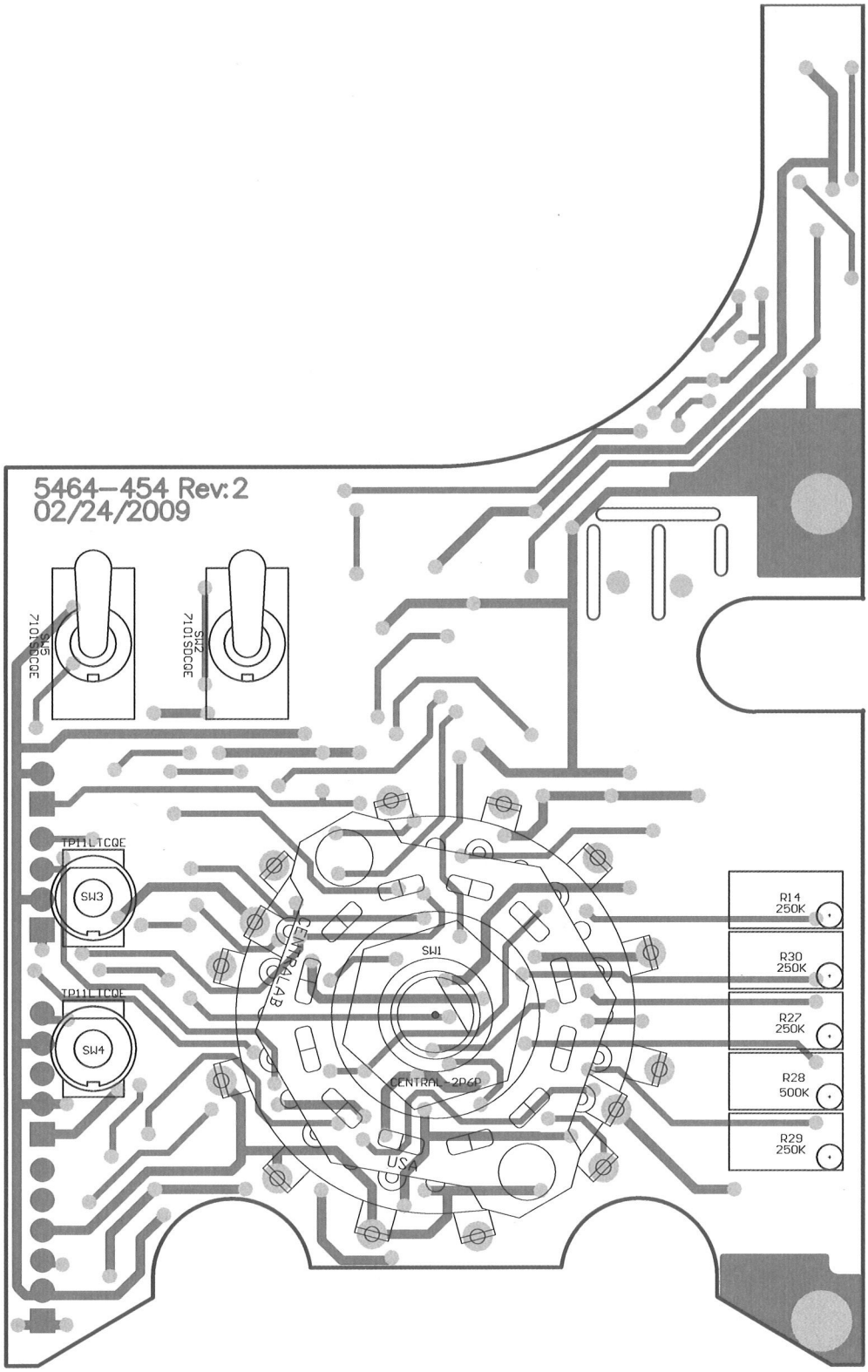

LUDLUM MEASUREMENTS, INC.	PO Box 810 501 Oak Street Sweetwater, TX 79556 U.S.A. 1-800-622-0828		
Title: MAIN BOARD			
Drawn: MC	02/24/2009	**Model:** 14C	
Design: DL	02/24/2009	**Board#:** 5464-454	
Approve: RDS	26AUN14	**Rev:** 2	
Print Date:		**SCALE: 1.00**	**Series** 464 / **Sheet** 455 A
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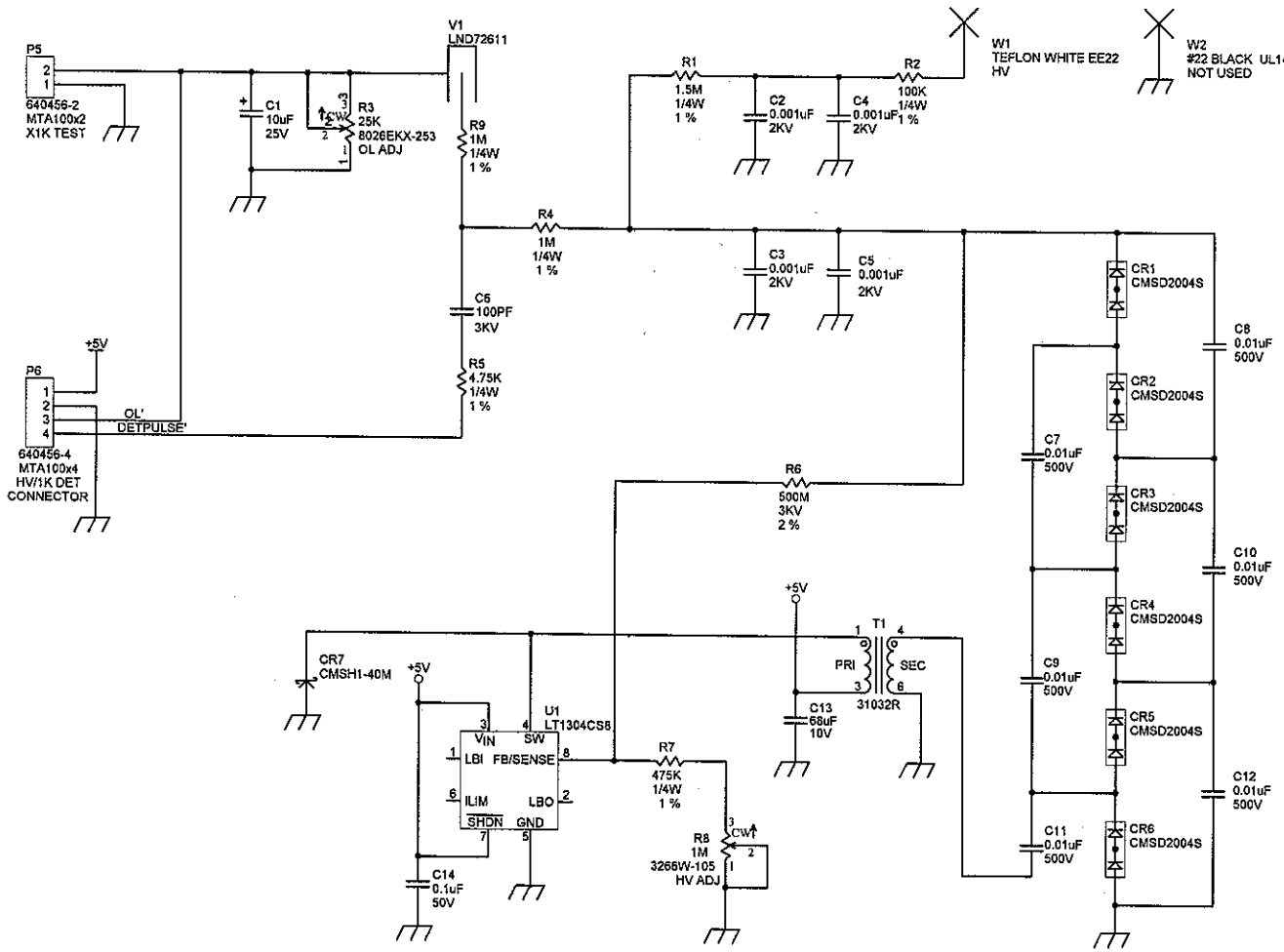

LUDLUM MEASUREMENTS, INC.		PO Box 810 501 Oak Street Sweetwater, Texas 79556 U.S.A. 1-800-622-0828	
Drawn: JK	16-SEP-05	Title: HV POWER SUPPLY	
Design: DL	16-SEP-05	Model: M14C	
Check:		Board#: 5464-302	
Approve:		Sheet: 1 of 1	Series 464 / Sheet 302
08:36:11	24-Feb-2011	Rev: 1.0	
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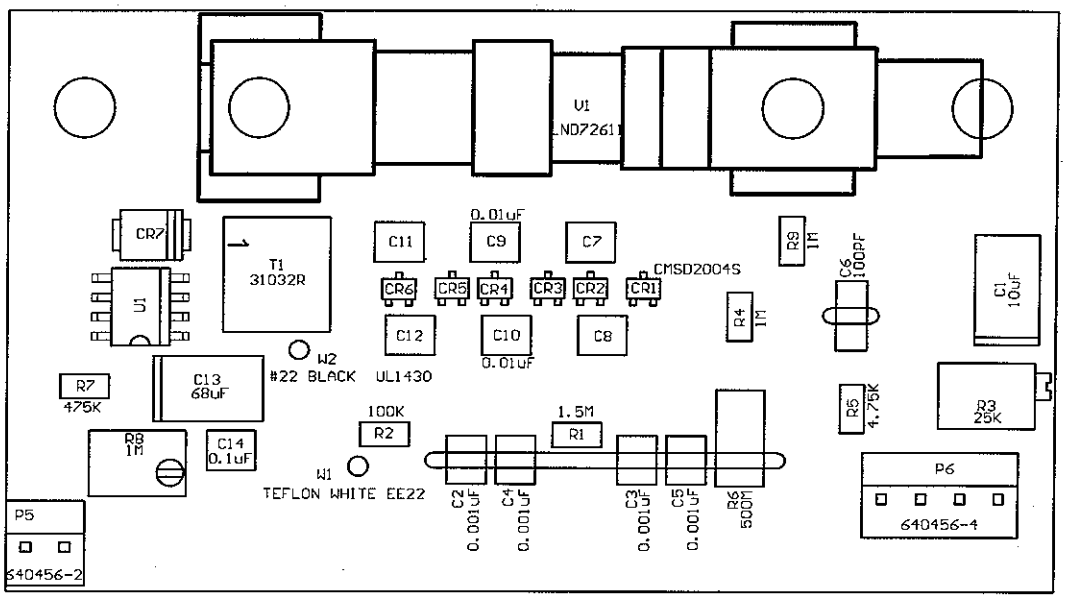
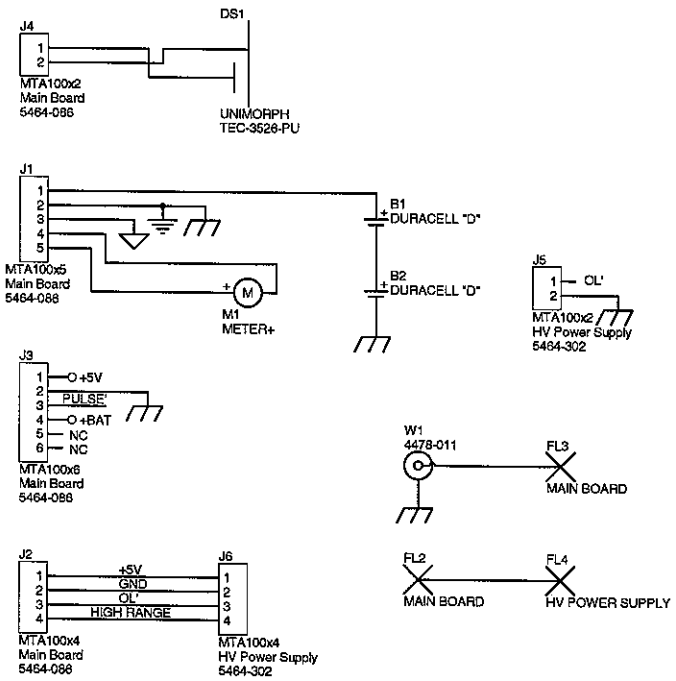


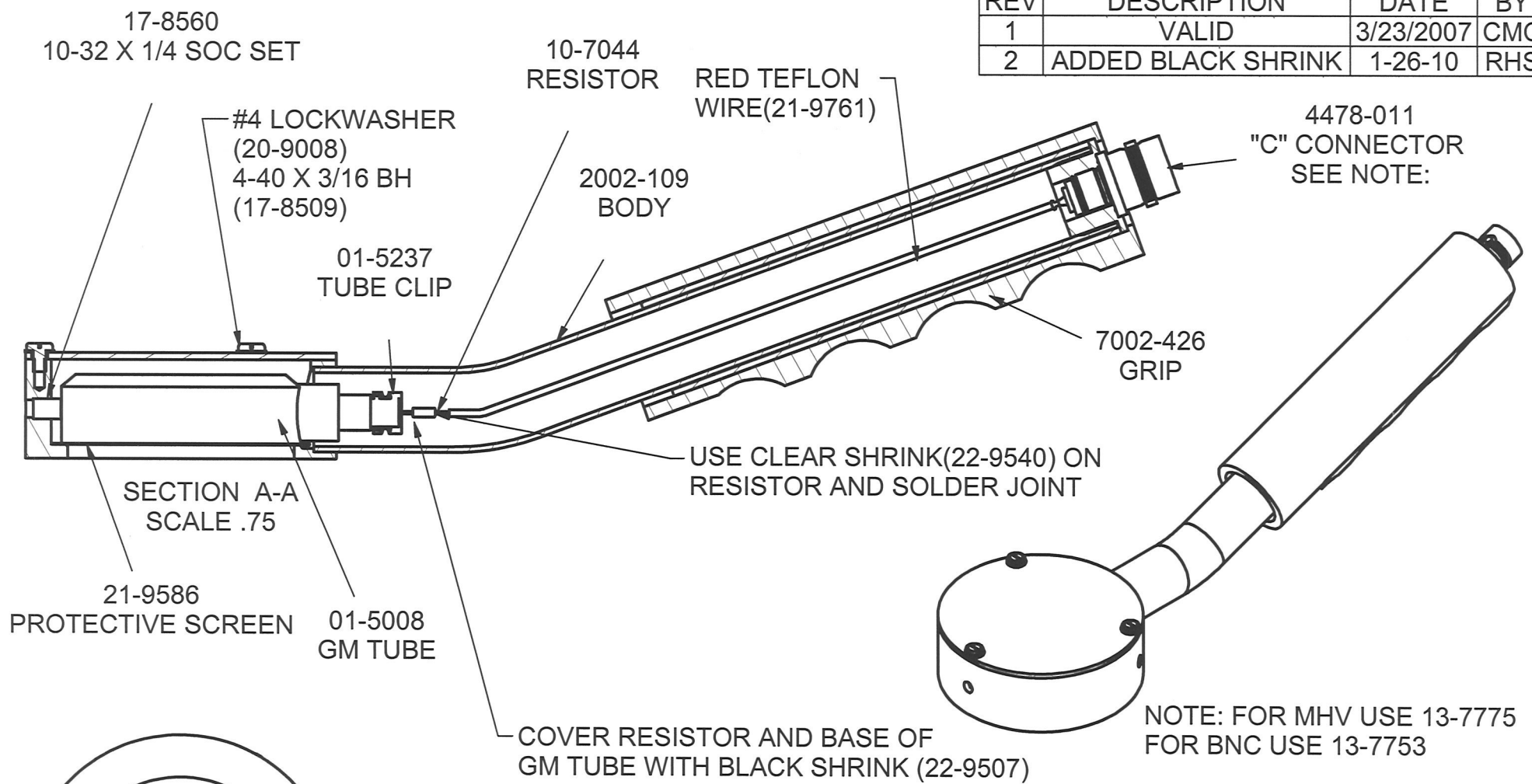
Drawn:	JK	16-SEP-05	Title: HV POWER SUPPLY		
Design:	DL	16-SEP-05			
Check:			Model: M14C		
Approve:	RSS	17 Feb 11	Board#: 5464-302		
			Rev: 1.0	Series 464	Sheet 303
			SCALE: 2.02		

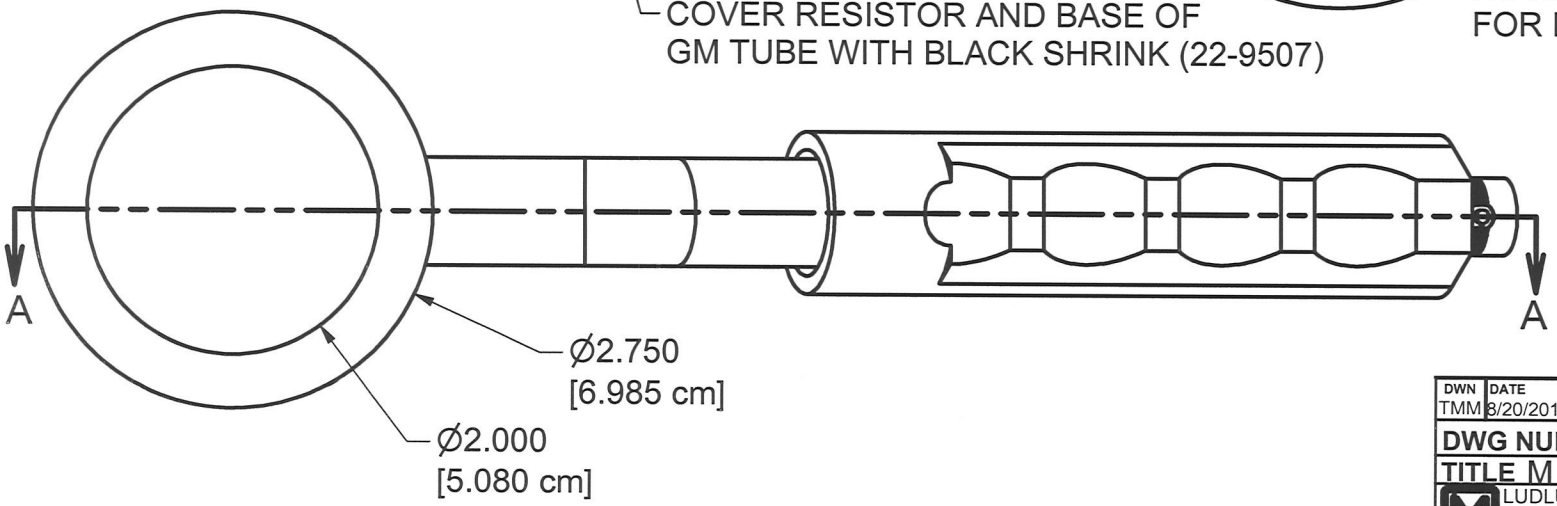


LUDLUM MEASUREMENTS, INC.
PO Box 810
501 Oak Street
Sweetwater, Texas 79556
U.S.A. 1-800-622-0828

Drawn: SA	09/01/06	Title: WIRING DIAGRAM	
Design: PW	09/01/06	Model: 14C	
		Board#: 464-172	
Approve:	1 Sep 06	Sheet: 1 of 1	Series 464 / Sheet 175
08:39:52	1-Sep-2006	Rev: 2.0	
464X175			

REVISION HISTORY			
REV	DESCRIPTION	DATE	BY
1	VALID	3/23/2007	CMC
2	ADDED BLACK SHRINK	1-26-10	RHS





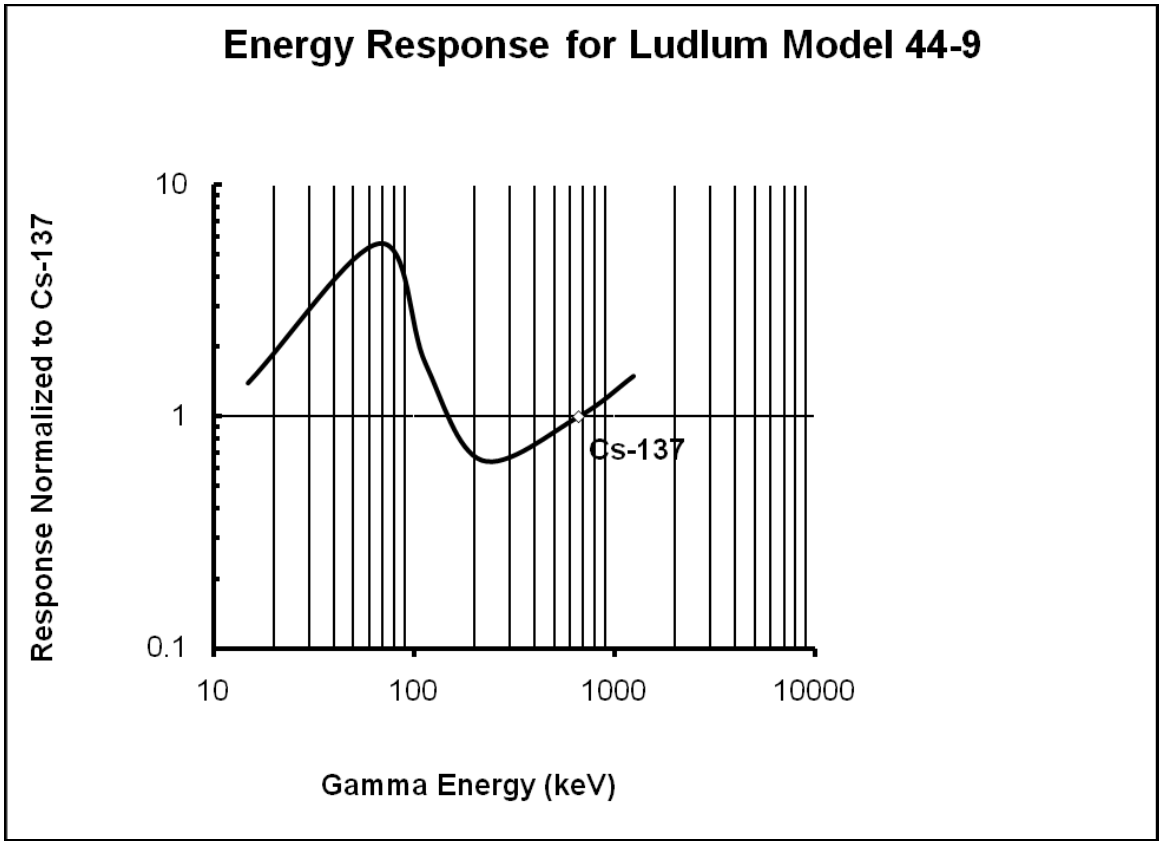
DWN	DATE	CHK	DATE	APP	DATE
TMM	8/20/2010			JGW	8-20-10

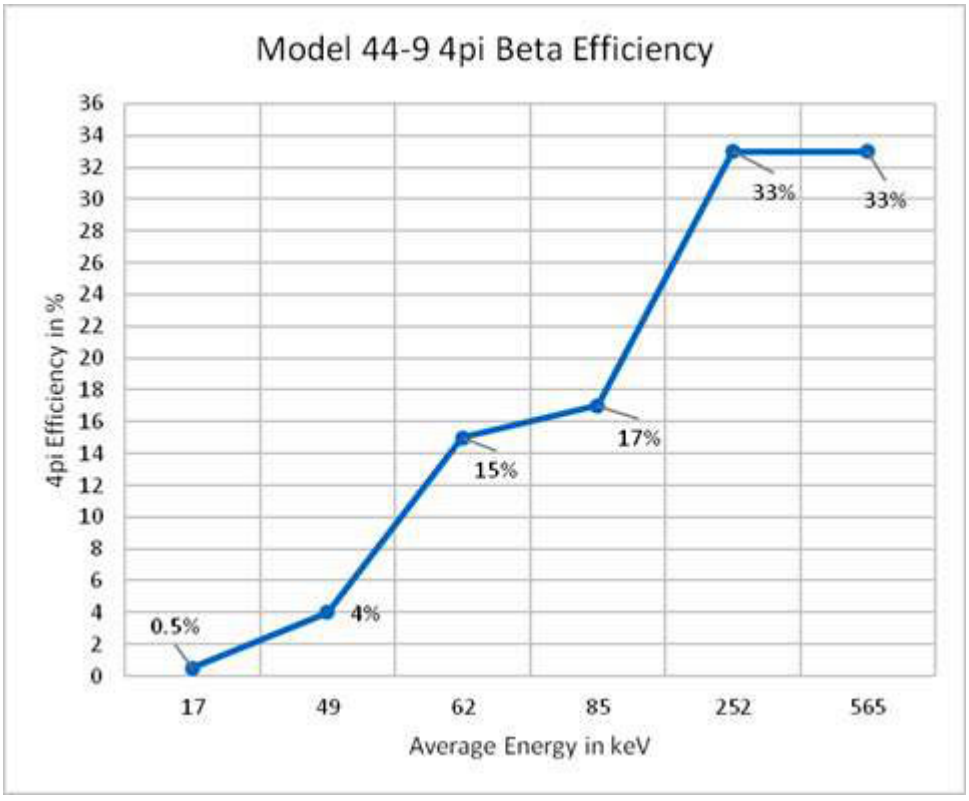
DWG NUM: 4002-290 SCALE: FULL ☐ OTHER

TITLE M 44-9 PANCAKE PROBE

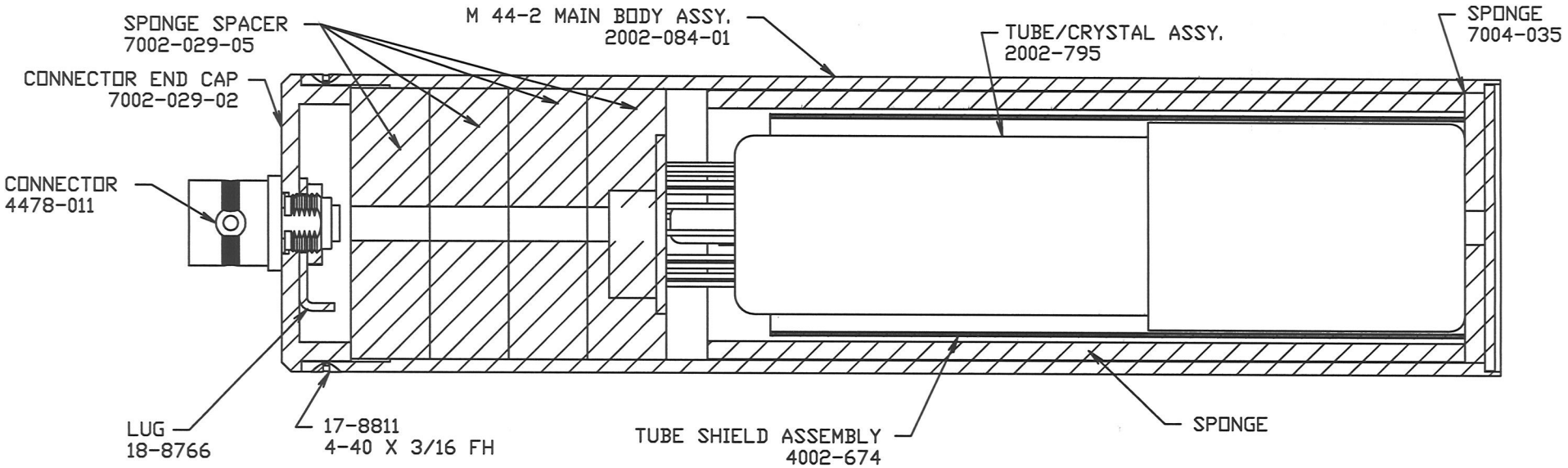
LUDLUM MEASUREMENTS, INC.
501 OAK STREET
SWEETWATER, TEXAS 79556

SERIES 2 SHEET 206


Energy Response for Ludlum Model 44-9
Response Normalized to Cs-137
10
1
0.1
Cs-137
10
100
1000
10000
Gamma Energy (keV)


Model 44-9 4pi Beta Efficiency
4pi Efficiency in %
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
0.5%
4%
15%
17%
33%
33%
17
49
62
85
252
565
Average Energy in keV

REV #	ALTERATIONS	DATE	BY
1	VALID	---	---
2	CHANGED 4002-510 TO A 01-5742	5-22-03	JSM
3	ECF# 1,609	11/25/03	CLW



DWN	DATE	CHK	DATE	APP	DATE
CLW	11/24/03			JMD	12-2-03

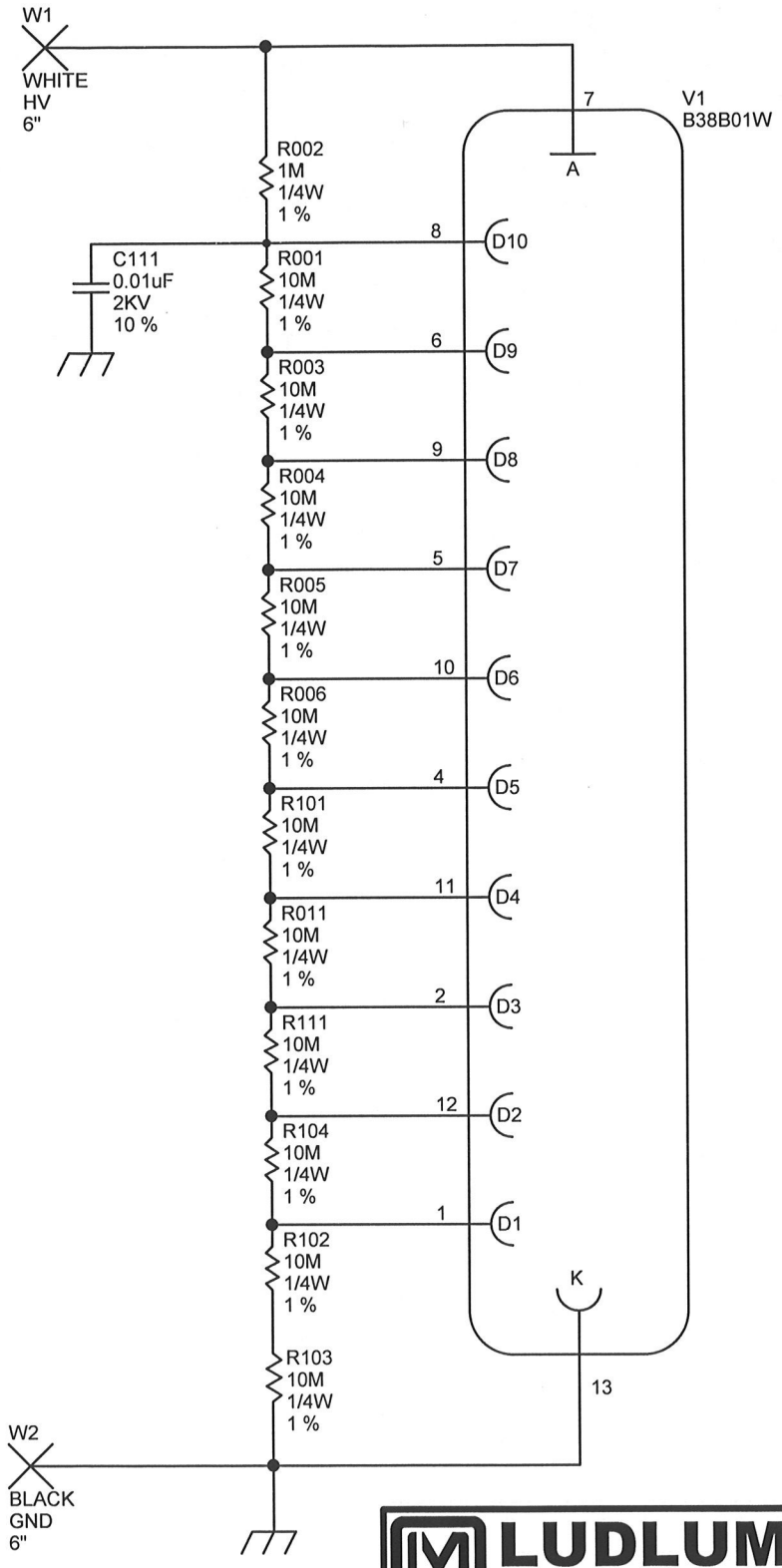
DWG NUM: 4002-289 SCALE: FULL ☐ OTHER 3/4

TITLE M-44-2 ASSEMBLY DRAWING

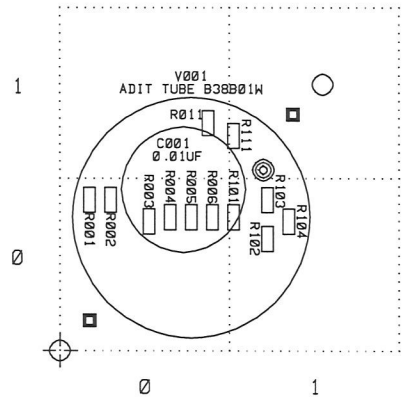
LUDLUM MEASUREMENTS, INC.
501 OAK STREET
SWEETWATER, TEXAS 79556

SERIES 2

SHEET 205A



LUDLUM MEASUREMENTS, INC.		PO Box 810 501 Oak Street Sweetwater, Texas 79556 U.S.A. 1-800-622-0828	
Drawn: CKB	25-JAN-07	Title: 1.5" VOLTAGE DIVIDER	
Design: DL	14-FEB-96	Model: VARIOUS	
Check:		Board#: 5002-502	
Approve:	15 Feb 11	Sheet: 1 of 1	Series 2 / Sheet 317
19:01:11	14-Feb-2011	Rev: 2.0	
002502R2P1.sch			



LUDLUM MEASUREMENTS INC. SWEETWATER, TX.						
DR CKB	02/14/96	TITLE: VOLTAGE DIVIDER BOARD				
		BOARD: 5002-502				
DSGN DL	02/14/96	MODEL: 1 1/2"				
APP JWS 10-24-07		FILENAME: BS002502				
COMPONENT	SOLDER	11:59:05	14-Jan-04			
		REVISION	SERIES	SHEET		
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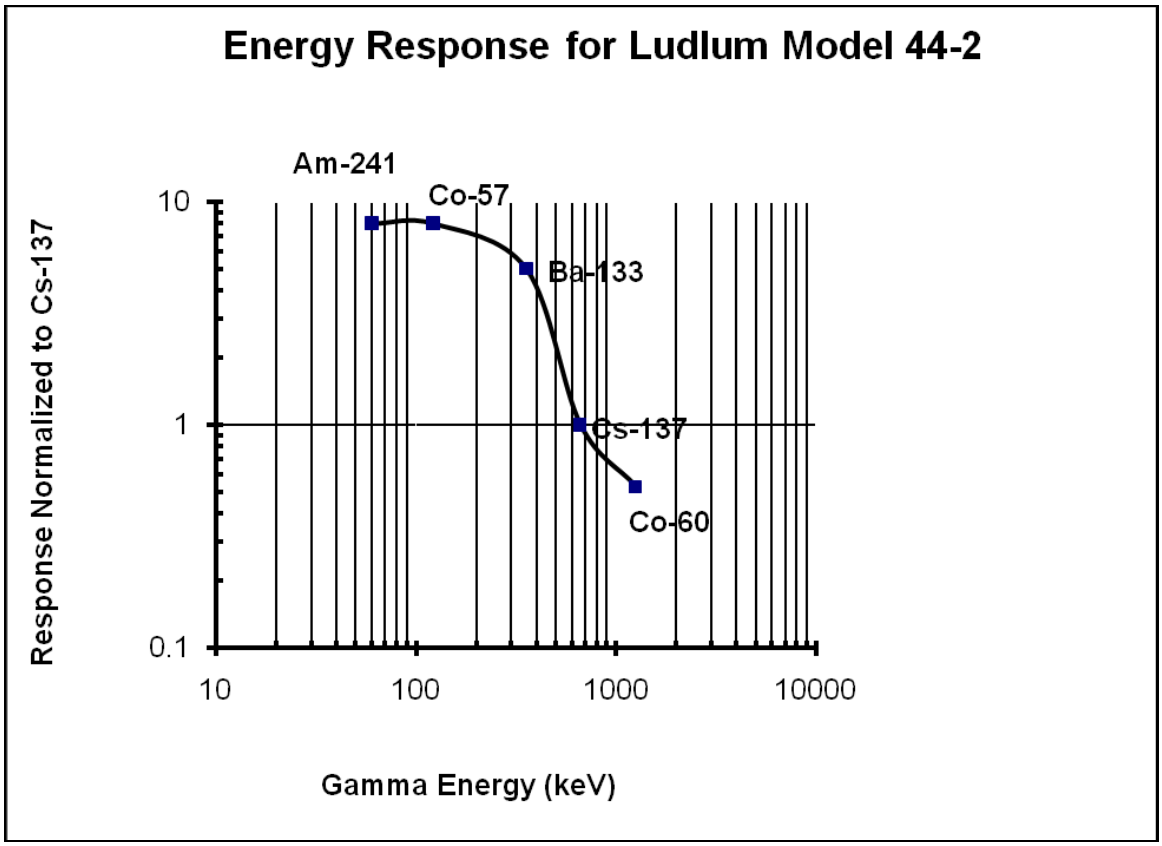
Energy Response for Ludlum Model 44-2
Am-241
Co-57
Ba-133
Cs-137
Co-60
10
1
0.1
10
100
1000
10000
Response Normalized to Cs-137
Gamma Energy (keV)